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FROM THE SEEN TO THE UNSEEN

By

JOHN H. BEST, B.Sc. (Lond.)

VICAR OF LITTLE MARLOW, BUCKS

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1929

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TO THE MEMORY OF
TALBOT BAINES
APART FROM WHOSE CONSTANT
ENCOURAGEMENT THIS VOLUME WOULD
PROBABLY NEVER HAVE SEEN THE LIGHT

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“ To the solid ground
Of Nature trusts the mind that builds for aye.”
Wordsworth.

“ Ever fresh the broad Creation,
A Divine improvisation,
From the heart of God proceeds,
A single Will, a million deeds.”
Emerson.

“ The invisible things of Him since the creation of the world
are clearly seen, being perceived through the things that are
made, even His everlasting power and divinity.”
St Paul.

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CHAPTER I

INTRODUCTION

IF it be true, as nearly all the higher religions have affirmed, that the Universe proceeds from God, that it is indeed His handiwork, then it would seem almost inconceivable that it should not in numberless ways bear unmistakable and emphatic witness to Him. We should expect that it would at least put the fact of His Existence beyond all reasonable doubt and, further, that it would enable us to reach certain more or less definite conclusions respecting His Character and the relation more particularly which He sustains to ourselves. In examining any product of human activity we have no hesitation as a rule in referring it to its true source, viz. human intelligence; and, should it happen to be some work of supreme art, it will be strange indeed if the soul of the artist is not somehow revealed in it. The great poem, the great picture, or the noble architectural design, derives much of its subtle charm from the way in which it seems to put us *en rapport* with its author and to let us to a certain extent into the secret of his personality. And if God be the Author of the Universe, "the Maker of Heaven and Earth and of all things visible and invisible," what more natural than to suppose that we should be able to find clear proof of His Existence, together with certain sure indications touching His inmost Self, as we survey the marvellous order, the intricate workmanship, and the surpassing beauty of the world around us?

To this it will probably be replied that, however likely it might seem at first that we should be able to reach certain definite conclusions on these matters, there are a number of facts in our possession to-day of so disheartening a kind as may well dissuade us from making any such attempt. The

facts referred to are those, of course, which in recent times have come to our knowledge, as the result of the enormous advance which has taken place in every department of Physical Science—facts which in conjunction with the theories based upon them have effected a complete revolution in our general outlook upon the Universe. There are at least three different directions in which our ideas have been profoundly modified. First, we have the recognition on all hands of the universality of the Reign of Law, which, as understood by many, seems to hold everything in its iron grip, suggesting to us in place of a Personal God a rigid system of purely mechanical causes and effects. Secondly, as a consequence of the vast progress which within the last few decades has been made in Sidereal Astronomy, we have had brought home to us, as never before, the Immensity of the Universe as regards both Space and Time. Light, travelling at the prodigious speed of 186,000 miles a second, has taken, we are told, more than 150,000 years to reach us from certain portions of the Milky Way, and anything between a million and a hundred and forty million years to reach us from those most mysterious of all celestial objects, the great spiral nebulae.¹ What are we, then, tenants of a little world like this—a mere grain of sand in comparison with the mighty All—that God, if there be a God, should treat us as of the smallest account? And thirdly, there is this seemingly so subversive Doctrine of Evolution, the offspring of these latter days, which in one form or another has most assuredly come to stay, and which, according to a certain currently accepted version of it, professes to explain Life and all its wonderful phenomena in such a manner as to render God wholly superfluous.

Granting, however, that there is evidence sufficiently strong to establish the truth of His Existence, there looms up the still more serious question as to His Character and His possible disposition, benignant or otherwise, towards our race. And here we are at once confronted with the eternal and apparently quite insoluble Problem of Evil. For if God, as most of us I imagine at one time or another

¹ J. H. Jeans, *Astronomy and Cosmogony*, p. 12.

have been taught, is a God of Love, if that really expresses the deepest truth concerning Him, then—to put the old question—how comes it, that in a world purporting to be the work of His hands there should be so much of suffering and of moral confusion, so much that has all too evidently gone amiss? The great European War, for example, with all its bloodshed, agony, and tears, and its rough trampling upon all the finer instincts of humanity—why did God not intervene to stop it? Why did He not for once at least break His imperturbable silence and pronounce judgment upon it? Did He really care, did it at all trouble Him, that in this little corner of His Universe so terrible and so ghastly a thing was taking place?

Again, we cannot close our eyes to the fact that a large amount of the suffering which is in the world is the result neither of man's folly nor of his sin. The volcano, the earthquake, the flood, the famine, and the fire, over none of which has he been able to secure more than a minimum of control, have each and all helped to contribute to the sum of human misery. Very puzzling, too, to those who would fain believe in the Divine goodness, is the way in which certain of the lower forms of life, such as the bacteria of disease, have been allowed to play havoc among the higher ones—man not excepted—and to carry out in them their destructive work.

The question, therefore, becomes a very urgent one: Are we forced by considerations of this kind to surrender as a beautiful, but now entirely discredited dream, that ancient article of Faith according to which God has been represented as a Being of infinite compassion and love? Nay, in view of all that Physical Science in these modern times has revealed of the faultless working of that colossal piece of mechanism (?) called the Universe, is there any compelling reason why we should continue to believe in God at all? Are we not driven, however reluctantly, to say,

He is only a cloud and a smoke who was once a pillar
of fire,

The guess of a worm in the dust, and the shadow of
his desire.¹

¹ Tennyson, *Despair*.

There are many, no doubt, who, in order to evade these difficulties and still retain their hold upon religion, have endeavoured to draw a sharp line of demarcation between what they are disposed to regard as two entirely independent spheres, viz. the sphere of Faith and the sphere of Reason. Reason, say they, may legitimately employ herself upon the facts of the external Universe and seek to build upon them a number of generalisations of a more or less provisional character, but she must remember that there are other truths which lie altogether outside her ken and with which, therefore, belonging as they do to the sphere of Faith, she is incompetent to deal. In other words, over against a certain class of truths, which we have somewhat unwillingly perhaps been compelled to acquiesce in, we are entitled to set up another, however irreconcilable with, and even antagonistic to, each other they may appear.

Such a procedure, however, creating as it does a kind of permanent schism between two very different sides of our nature, is not only eminently unsatisfactory, but will not bear the test of examination. For whence do men derive those truths which are said to belong exclusively to the sphere of Faith? They derive them from one or other or both of the two following sources: (*a*) their inner moral and religious experiences; (*b*) some form of special Divine Revelation which, whether rightly or wrongly, they believe to have been communicated to mankind at some distant epoch in history. But it is to be observed that in the case of neither of these sources is it possible to exclude the work of Reason. Our moral and religious experiences are not isolated phenomena, but stand in closest relation with numberless other elements, all of which help to make up our conscious life. They are, therefore, along with the rest, proper subjects to be dealt with by the important and ever-growing science of Psychology, which on its philosophic side has to determine among other things the validity of our experiences, of whatever kind they may be.

Again, as to any Divine Revelation, and especially such a one as the Christian Religion has all along presupposed, it is obvious that for our knowledge of it we are entirely

dependent upon certain important documents which have been handed down to us from the past. The remark not only applies to the writings of the Old and New Testaments, but for those who would add to the authority of the Scriptures the authority of the Primitive Church, it applies equally to those writings from which alone we can ascertain what the mind of the Primitive Church really was. Thus in both cases we are driven back upon certain documents. But for documents to be of any service in the establishment of religious truth they must be subjected to much patient preliminary investigation. All kinds of questions are apt to crop up in connection with them—as to their date and authorship, the purposes for which they were originally written, their correct transmission down the centuries, and above all, their degree of reliability and the extent, therefore, to which we may regard them as reflecting in very truth the Mind of God. Now all this implies considerable intellectual labour on the part of those who are specially qualified to deal with such matters; in other words, it implies the exercise of Reason. Hence, whatever meaning we may be inclined to attach to the term “Faith”—a subject, however, on which I do not propose to enter—it is clear that no such sharp line of demarcation can be drawn as that to which I referred above.

To return from this digression, the question of paramount importance, of course, is this: Are we really obliged, on the strength of our present-day knowledge of the Universe, to abandon ourselves to those exceedingly melancholy conclusions to which I alluded just now? Is God no more than a figment of the imagination, an idea begotten in men's minds in the days of ignorance and superstition? Or, in case proof should be forthcoming sufficient to convince us of the truth of His Existence, what warrant have we, in view of all the sin and suffering which are in the world, for believing in Him as One who entertains the slightest regard for the well-being and happiness of His creatures and of us men in particular?

I need hardly say that it is with considerable diffidence that I am attempting in the following pages to arrive at

some sort of answer to these questions, and to find out what measure of light it may be possible to cast upon them.

While accepting *con amore* all the well-established facts and generalisations of modern Science, the Doctrine of Evolution included, and not losing sight of the many grave difficulties which beset one in connection with the Problem of Evil, it appears to me that these things are capable of a very different interpretation from that which a materialistic philosophy has too often tried to put upon them. I think that, without any twisting of facts or ignoring of difficulties, we can rise to such a conception of the Universe as will fully vindicate our belief in God, and our belief in Him as One who is absolutely good and is continually working for the realisation of certain far-off beneficent ends.

And here let me say once for all that the evidence on which I intend to rely stands entirely apart from any that may possibly be derived from the perusal and careful study of ancient documents. This means, of course, that in the present volume, whatever may be my own personal views, no cognisance will be taken of what is generally spoken of—in the restricted sense—as Revealed Religion. The problem, therefore, with which I set out to deal may be expressed thus: Suppose that all documents of the kind just alluded to were clean swept away and that all memory of their contents were effaced from men's minds, what conclusions, if any, of a religious character should we be able to draw from an impartial survey of the facts of the Universe as they are known to us at the present time?

In pursuing such a line of inquiry I have no intention of casting the least disparagement upon any other sources through which, as in the case of an Historic Revelation, religious truths may have reached mankind. Such truths, on the contrary, may possibly find a firmer basis on which to rest, if our proposed inquiry should lead to any assured results.

Among our religious beliefs the two which, as already hinted, stand out as of prime importance—because fundamental to all the rest—are our belief in the Existence of God, the One Supreme Spirit, the Author and Sustainer of

the Universe, and our belief in Him as a Moral Being, who on that account really cares for His world, and especially for those in it who happen to be His highest creatures. In the present work we shall consider these two in the order just mentioned, and we shall consider them separately, inasmuch as the arguments in their favour are of an entirely different kind. There is this further reason for doing so. When any serious disaster has occurred involving the destruction of a number of human lives—and especially when it is due to the working of purely inorganic forces—there are always people ready to say, “How can we any longer believe in the Existence of God, when events such as these are allowed to happen?” But surely this is the result of a certain confusion of ideas. What such an event really tends to cast doubt upon is not our belief in the Existence of God, but our belief in His perfect goodness and the nature of His providential dealings with men. There might still be a God, although we might be forced to conceive of Him as wholly indifferent to all the sorrows and sufferings which afflict our race.

Bearing this important distinction in mind, I shall defer to the concluding chapters of this book everything that I have to say about the Moral Character of God and the manner in which, as it seems to me, we may best approach the great Problem of Evil.

The reader will observe on examining the table of contents that the whole of the earlier, and by far the greater portion of this work, is devoted to the consideration of matters of a biological order. This is because it is precisely in the phenomena of Life that I think we may discover the surest grounds for our belief in a Supreme Mind, as also for our belief in an entire Unseen Realm of things forming the background, so to speak, of all that we are able to perceive through our bodily senses. Hence in the next chapter, while refraining from any attempt to offer a definition of Life—always a quite futile undertaking—I shall try to indicate as succinctly as I can what are its chief characteristics, while in the immediately following chapters the topics to be discussed will be “Life and Energy,” “Life and

Purpose," and the nature of the differences which have arisen in the course of Evolution between Plants and Animals. In Section II a more detailed description will be given of the animal organism and of its extremely varied activities, special stress being laid on the extraordinary purposiveness which distinguishes them. This will be succeeded in Section III by an account, very brief but, I trust, sufficient, of that truly astounding process by which the individual organism, with all its immensely complicated and closely inter-related parts, is gradually developed out of a microscopically minute and, to the eye at least, quite simple speck of living matter, viz. the germ-cell. Having pointed out the complete failure of every effort to explain mechanistically what happens in this process, I shall proceed in Section IV to draw from it certain highly important conclusions. This will prepare the way in Section V for a number of others based on a consideration of the Life-System of our planet as a whole. Next, I shall go on in Section VI to treat of the bearing upon these results of our enormously extended ideas in reference to the size and duration of the Universe as revealed by Modern Astronomy. Lastly, in Section VII, I shall direct attention to those matters already referred to of a totally different kind, viz. the Character of God, the relation in which He may consequently be supposed to stand to ourselves, the nature and sources of Evil, and the light in which we may venture to regard the whole of that exceedingly difficult question. In the concluding chapter the subject under discussion will be the Future Life, and such evidences as may be forthcoming in support of it.

In the course of my argument I have introduced a considerable amount of detail, most of which is matter of common knowledge among those who are at all versed in the subjects referred to. But I have done so of set purpose, because the readers whom I have had more particularly in view are not the scientifically expert, but those rather whose early education and subsequent reading have led them along very different lines, and to whom, therefore, much which is contained in the following pages will perhaps be un-

familiar. I have avoided, too, all mathematical symbols and discussions of a purely philosophical nature, and have taken special care not to employ any scientific terms without having previously explained them. The illustrations scattered here and there throughout the volume will, I trust, materially help to make my meaning clear.

Finally, I desire to express my deep obligation to the many authors whose works I have consulted, and to several others who, in answer to my inquiries, have kindly supplied me with much valuable information.

Note.—I have taken no account in the following pages of the modern Theory of Relativity. The subject is too abstruse for the ordinary non-mathematical reader. Besides, its omission in no way invalidates my general argument.

CHAPTER II

LIFE : ITS CHIEF CHARACTERISTICS

THE various objects in the world around us fall naturally into two distinct classes according as they exhibit or do not exhibit the phenomena of life. To the former class belong, of course, all the different species of plants and animals, including ourselves, while to the latter belong the rocks and mountains, rivers, lakes, and seas, the all-enveloping atmosphere and the heavenly bodies. As in this and in most of the following chapters we shall chiefly be concerned with the things which have life, some sort of a definition of life might perhaps be expected here. But the truth is, every definition of it hitherto given has proved wholly inadequate, and for the simple reason that life is far too complicated and many-sided a thing for its meaning to be compressed within the limits of a single formula. Our best plan, therefore, in order to gain some preliminary acquaintance with the subject, will be to consider one by one the principal points which distinguish living beings from lifeless things. I will arrange them in a series of numbered paragraphs.

1. First, every living being, from the highest to the lowest, possesses a certain definite structure. It is composed of a number of parts often differing greatly from one another, and yet so closely interlinked as to form a single whole—a little world in itself standing over against the far greater world outside.

2. Again, not only is every living being the seat of numberless activities, but in a state of health its various parts are all working together in perfect harmony and for the realisation of certain definite ends. It is because of this property displayed by all living things that we

have come to speak of them as *Organisms* and of their several parts as *Organs*. Further, the special work performed by any organ is generally described as its *Function*. Thus in the human body the stomach, the lungs and the heart are the organs which have for their respective functions to digest food, to take in oxygen and to maintain constantly the circulation of the blood.

3. Another remarkable property of living things is the faculty, which to a greater or less extent they all possess, of repairing any injuries which they may have sustained, provided they are not of too serious a kind. Thus a wound will heal, and the edges of a fractured bone will grow together again if properly set. It is quite otherwise, as we know, with any merely man-made machine. If the hands of a watch come to grief or the mainspring unluckily gets broken, it must be sent to the watchmaker to be put to rights. It is wholly incapable of mending itself. Among certain of the lower forms of life the faculty referred to has been developed to an extent truly amazing. Thus a lobster, if deprived by accident of one of its long claws, will immediately set to work to grow itself another, though the organ in question, with its elaborate arrangement of muscles and nerves and with its hard encasing shell, is by no means the simple thing which the casual observer might be inclined to think. Again, a freshwater polype can be chopped, it is said, into almost any number of pieces, when each piece will gradually round itself up into a complete animal. Still more remarkable is the case of the newt. You may remove from its eye the little translucent, accurately curved lens which enables it to form a picture of the outside scene, but the loss will not be for long; in due course the eye will have effectually provided itself with another lens equally good. Imagine a human being, however skilled, who could construct an optical instrument capable of performing a similar feat!

4. Next, we come to that characteristic of living things which is perhaps the most wonderful of all, viz. their power of growth. It would greatly surprise us if, after purchasing a watch, we found that it could execute its own repairs;

but I think it would surprise us still more if we found, as the result of careful measurements, that month by month it was steadily increasing in size, and not only so, but increasing in complexity as well, adding to itself here a wheel and there a wheel, and numberless other little contrivances which were certainly not there when we first bought it. But such supposed behaviour on the part of a watch would be as nothing compared with what actually occurs in the case of every living thing, and especially during those early hidden stages which precede hatching or birth. As to increase in size, we all know how great is the difference between the new-born infant and the full-grown man; but perhaps we may not be aware that every human being to begin with is no bigger than a minute particle of matter $\frac{1}{100}$ th of an inch in diameter.¹ According to a somewhat curious calculation, if we suppose all the minute particles to have been packed together, which by their subsequent growth have developed into the entire population of the British Empire, they would have occupied no larger space than that of a cube measuring $2\frac{3}{8}$ inches each way, or that of an ordinary cricket ball. Yet out of that comparatively small amount of matter have been developed all the 400 millions of human beings now under our flag, with all their infinitely varied physical and mental peculiarities.

But again, as already intimated, a living organism during its period of growth not only increases in size but in complexity. To give an illustration: If the contents of a hen's egg are poured out into a dish, we shall see floating on the surface of the yolk a small round disc about the size of the tip of one's finger. It is what is known technically as the *Blastoderm*, and represents the stage at which the chick has arrived at the time when the egg was laid. But although it already possesses, as the microscope will show, a certain amount of structure, there is no sign in it yet of any of those organs which we generally recognise as such. It has neither

¹ Sir A. Keith, *Human Embryology and Morphology*, p. 1. Also, according to McMurrich (*The Development of the Human Body*, pp. 468, 469), the weight of a human being twenty-one years of age is on an average 109 million times greater than that of the ovum from which it has been developed.

head, nor limbs, nor brain, nor heart, nor any trace of a digestive system ; but all these would have begun to appear in the course of a few days, if only we had allowed the hen to sit upon the egg, or had placed it inside an artificial incubator. Moreover, in three weeks' time the whole of the wonderful process would have been completed. A tapping would have been heard inside the shell, presently a little beak would have thrust itself through, and not long afterwards the chick, alive and alert and with all its parts finished off to perfection, would have made its grand entry into the outside world. And what happens with the chick happens in all essential respects with ourselves, and with every one of the countless animals and plants which inhabit the earth. Each attains its adult form by a more or less similar process, and the process is one which is incessantly going forward, wherever Life has succeeded in establishing itself, whether in the ocean depths or in shallow seas, in rivers or lakes, in the air above or on the general surface of the land.

5. We have next to see that although an organism is in many respects complete in itself, it is nevertheless absolutely dependent upon its surroundings, its so-called *environment*, if it is to maintain itself alive. Thus it must be in a temperature neither too hot nor too cold ; it must have plenty of water and fresh air, and above all it must be supplied with sufficient food. How else, indeed, could it grow and effect all that extraordinary increase of size which growth implies, except by taking in substances from outside ? But one of the most remarkable things is that whatever may be the particular substances on which an animal feeds, it always manages to transform them into its own substance, or rather into those many different kinds of substance which it needs for the construction of its bones, muscles, nerves and other tissues. Consider, for example, an animal which, like a sheep, lives on a purely vegetable diet. For in this case, the mutton chop which serves us for a meal and the woollen wrap which keeps us warm in winter have both alike been ultimately derived from the grass and other herbage on which the sheep has fed. And as with animals so also

with plants. Their food, which is practically the same for them all, is of the simplest possible description—water containing small quantities of mineral matter in solution, got out of the soil, and a gas, *Carbon dioxide*, got out of the atmosphere. And yet out of these inert and apparently unpromising materials all the wealth and marvellous variety of the vegetable world are perpetually being produced. It is Life, the Arch-Magician, which takes of the air and the moisture and the dust of the earth, and transmutes them, now into the sturdy strength of the long-enduring oak, and now into the fragile beauty of the passing rose.

6. But food is required by an organism not only for purposes of growth, for self-repair, and for the manufacture of all the needed substances ; it is required, and particularly in the case of an animal, for the maintenance of those numerous activities, which have been briefly referred to in paragraph 2 as constituting the very essence of its life. It is its food, in fact, which furnishes it with the energy, apart from which those activities could not possibly be carried on. Thus it plays a part, closely similar to that of the fuel which is supplied to a steam-engine, and which by its consumption is the source in it of its driving power. But on this subject, and on some of the very important consequences flowing from it, more will be said in the following chapters.

7. Now in all the foregoing points, with the single exception perhaps of the last, a living organism clearly transcends an ordinary machine, for the latter can neither convert into its own substance any substances which may be supplied to it from outside, nor can it repair itself when out of order, nor can it effect growth. Still less can it reproduce its own kind. An aeroplane does not scatter seed or lay eggs ; an ocean liner does not bring forth young. It is needless to say, however, that the faculty of reproduction resides normally in every living thing, when once it has attained maturity. It is Nature's way of making good the gaps caused by death. In the majority of instances the process is brought about by the co-operation of the two sexes, for from top to bottom of both the Animal and Vegetable

Kingdoms, or nearly so, there is the distinction between males and females, although in a very large number of plants, and among certain also of the lower animals, the male and female organs are found on the same individual. There are, of course, other modes of reproduction besides the sexual one, but they are, generally speaking, of quite minor importance.

It will be observed that the points hitherto referred to relate almost exclusively to the individual organism, but besides these there are others which only come into view when we take into consideration the Life-System of our world as a whole. To these, therefore, we must now direct attention.

8. And, first, we have to take note of the fact, whatever may be its significance, that such a System as that just mentioned actually exists. Life, for some reason or other, has appeared on the earth in the form of a vast multitude of species, all differing from one another in a great variety of ways, and often differing from one another very widely indeed. Thus there are said to be at least 25,000 already named vertebrate animals, ten times as many invertebrate ones, and about as many plants. Again, within the limits of each species we have an enormous number of individuals, which although closely alike, still show certain differences. But what is the inner reason for this extraordinary multiplicity in the organic world? Why should not Life, instead of breaking itself up into these innumerable fragments, have appeared, as it might conceivably have done, in the guise, say, of one solitary undying individual? ¹ Such a question may seem perhaps scarcely worth the asking, things being as they are, but if it should turn out that the Universe can only be interpreted as the work of a Supreme Mind, some sort of answer to it ought, one would think, to be possible. In any case, the well-nigh infinite variety of forms which the organic world presents is one of its most astonishing features, and provides us with almost endless food for reflection.

¹ Bergson, *Creative Evolution*, p. 56.

In order mentally to cope with this variety and to bring it for purposes of study more easily within our grasp, different systems of classification have from time to time been devised. These have resulted to-day in what is known as the *natural* system of classification, which, however, is continually undergoing revision, as our knowledge of the world of living things gradually extends and becomes more and more precise. It need scarcely be said, perhaps, that under any system of classification the first great line of division is that which marks off the Animal from the Vegetable Kingdom; though in the case of several of the lower organisms it has often been found difficult to decide in which of the two kingdoms they should be placed. Next to this principal division we have in descending order the following lesser ones, viz.: Sub-kingdoms (or Phyla), Classes, Orders, Families, and Genera, till at last we come down to actual Species. For example, the Tiger Moth (*Arctia caia*) belongs, together with all the rest of the Moths and Butterflies, to the order of the Lepidoptera, so named because of the beautiful scales upon their wings and other parts. But the order of the Lepidoptera is only one out of the eight orders constituting the class of the Insecta (or Insects), which are characterised by their bodies being divided into three very sharply marked-off regions, viz. a head, a thorax, and an abdomen. The Insects in their turn form one of the five classes belonging to the phylum of the Arthropoda or animals with jointed legs; and lastly, the Arthropoda are just one out of the ten or twelve phyla which make up the entire Animal Kingdom.¹ But for further information on this subject reference may be made to the note at the end of this chapter.

In the classification of animals and plants attention has often to be directed to the important fact that some of them stand high up and others low down in the scale of life, whilst between these extremes come a vast number of others occupying intermediate positions. It may be as well, therefore, to explain what exactly the terms "high" and "low" mean in this connection. The distinction has

¹ Parker and Haswell, *Textbook of Zoology*, vol. i.

little, if anything, to do with mere size. Thus a bee, small as it is, is a much higher animal than a sea-anemone; a common daisy is a much higher plant than even one of those huge seaweeds several hundreds of yards in length which have been found flourishing far down in the ocean depths.¹ The question really depends on the degree of organisation to which the animal or plant has attained. A sea-anemone, for example, possesses only the most rudimentary nervous system; it has no blood, no definite breathing apparatus, no organs of locomotion, no discoverable eyes; whereas a bee is duly provided with all of them. Again, increase in organisation invariably carries with it increase in the number and complexity of the relations which a living thing sustains to the environment. Compare, for instance, as to their nature and extent, the relations to the Universe at large which are borne by an earthworm and by a human being respectively.

9. But, again, if Life presents itself to-day in the form of a vast array of species, each consisting of a large number of individuals, we know, from the remains of plants and animals buried deep in the rocks beneath our feet, that this state of things has prevailed down all the immense periods of geological change.² Never for one instant during that time has this marvellous procession, this strange, onward-moving pageant of living things, ceased. And although there has been the continual perishing of individuals and of species and of whole tribes, Life itself, un baffled by death, has triumphantly pursued its upward path, embodying itself in ever higher and higher forms, until apparently it has reached its final, its supreme goal in Man.

Moreover, it was just because Life from the first split itself up into myriads of units, allotting to each of them at the most only a brief span of years, that reproduction became necessary, as well as that wonderful process by which in all the higher organisms the minute germ-cell develops

¹ Thomé, *Textbook of Structural and Physiological Botany*, p. 258.

² According to certain recent estimates it is 1200 to 1400 millions of years ago since life first appeared upon the earth.

into the fully grown individual. If there had been no reproduction, clearly death would speedily have made an end of Life. Again, if there had been no death, reproduction would have so overstocked the earth as to render existence on it unendurable; and, once more, if there had been neither reproduction nor death, the great Evolutionary process, to which we must now refer, would never have been started on its course.

10. Till comparatively recent times it was the prevailing belief that each of the countless species of plants and animals inhabiting the earth had originated separately, either as the result of a special Divine creative act, or through the operation of certain unknown purely natural causes. Opposed to this belief is the modern doctrine of Evolution, which has completely revolutionised all our ideas upon the subject. It teaches that the various forms of life on our globe, both those existing now and those which have existed in the past, are all genealogically related to one another by the ties of a common descent. They together constitute, in fact, one great family, in which Man, as chief member of it, occupies the highest place. But this necessarily implies that species cannot be the immutable things in the sense formerly supposed, but must be capable, however slowly, of undergoing modifications and of thus giving rise to species entirely new. And this, as is now believed, is what has continually been taking place during those immense cycles of time which have elapsed since Life first became possible on the earth.

That the theory in question is true seems to have been put beyond all reasonable doubt by the many and very strong converging lines of proof which have been adduced in its support. But I shall have occasion to say more on the subject later on, as also on that matter of quite paramount importance, as to how we are to conceive of the cause or causes which have brought Evolution about.¹

11. It would be a mistake to suppose that what has happened in the organic world has been merely an Evolution in the complexity of material structures and in their corre-

¹ See Chapters XXIV, XXV and XXVI.

sponding functions. Side by side with it, in the animal kingdom at least, there has been a gradual Evolution of mind—of memory, thought, feeling, purpose, will—and these in Man have undergone so extraordinary a development as to set him on a pinnacle far above all other forms of life. How it was possible for this to come about in a Universe in which, to begin with, Mind was not, is a problem to which, as it appears to me, no solution can be found; but of this I shall have much more to say later on.

12. Death, reproduction, growth—and we may now add Evolution—all these are mutually implicated, and are apparently the result of that great all-determining fact already mentioned, that Life, instead of remaining an undivided whole, has distributed itself among countless individuals. But in connection with this fact there is one other thing to be noted, which may ultimately turn out to be of great significance. It is that Life on our little planet has by no means proceeded along its path in unbroken unity with itself. Though in the case of each separate organism perfect harmony may have characterised the working of its several parts, it has been far otherwise with Life regarded as a whole. There has somehow entered into it a disturbing element, which as between the individual units has been the source of incessant strife, leading each of them, often in complete disregard of the welfare of all the rest, to strive only after its own private and particular ends. But how is it, we may well ask, that in this ordered Universe of ours, in which sun, moon, and stars all move in unerring obedience to Law, there should have happened in the domain of Life this strange admixture of harmony and discord? Can any explanation of it be given? Only perhaps towards the end of our inquiries shall we come within sight of a possible answer to the question.

NOTE ON THE CLASSIFICATION OF ANIMALS

The various forms of animal life may be classified as follows:—

- I. PROTOZOA: Amœbæ, Foraminifera, Radiolaria, Infusoria.
- II. SPONGES.
- III. COELENTERATES: Fresh-water Polypes, Jelly-fish, Scæanemones, Corals, Ctenophors, etc.

- IV. UNSEGMENTED WORMS : Flukes, Tape-worms, etc.
- V. SEGMENTED WORMS : Earth-worms, Lob-worms, Leeches, etc., with which may be included the Rotifers.
- VI. ECHINODERMS : Starfishes, Feather-stars, Brittle-stars, Sea-cucumbers, Sea-urchins.
- VII. MOLLUSCOIDS : Sea-mats, Lamp-shells.
- VIII. MOLLUSCS :
 - (1) Bivalves : Mussels, Cockles, Oysters, etc.
 - (2) Univalves : Periwinkles, Snails, etc.
 - (3) Cephalopods : Cuttle-fish, Nautili.
- IX. ARTHROPODS :
 - (1) Crustaceans : Crayfish, Crabs, Lobsters, Prawns, Barnacles, Wood-lice, etc.
 - (2) Myriapods : Millipedes, Centipedes.
 - (3) Arachnids : Scorpions, Spiders.
 - (4) Insects : Earwigs, Cockroaches, Grasshoppers, Flies, Dragon-flies, Butterflies, Moths, Beetles, Bees, Wasps, Ants, etc.
- X. CHORDATES :
 - (1) Primitive and sometimes degraded forms : Amphioxus, Sea-squirts, etc.
 - (2) Fishes : (a) Round-mouthed fishes ;
(b) Ordinary fishes with proper jaws ;
(c) The Dipnoi or Lung fishes.
 - (3) Amphibians : Newts, Salamanders, Frogs, Toads.
 - (4) Reptiles : Lizards, Snakes, Turtles, Tortoises, Crocodiles, and multitudes of extinct forms.
 - (5) Birds : (a) The Archæopteryx, long extinct, showing certain reptilian features.
(b) Toothed birds, also extinct.
(c) Modern birds, with bills instead of teeth.
 - (6) Mammals : (a) Monotremes : Duckmole, Spiny Ant-eater.
(b) Marsupials : Kangaroos, Wombats, Opossums.
(c) Placentals : all the higher four-footed beasts, Apes, and Men.

In the above list the arrangement is in the main from the lower up to the higher forms, but it must be distinctly understood that the true order is by no means a linear one. It is treelike in character, branching out in several directions, as is shown in the accompanying diagram, which is intended to indicate roughly the supposed genealogical relations of the principal groups and of some of their minor ramifications.

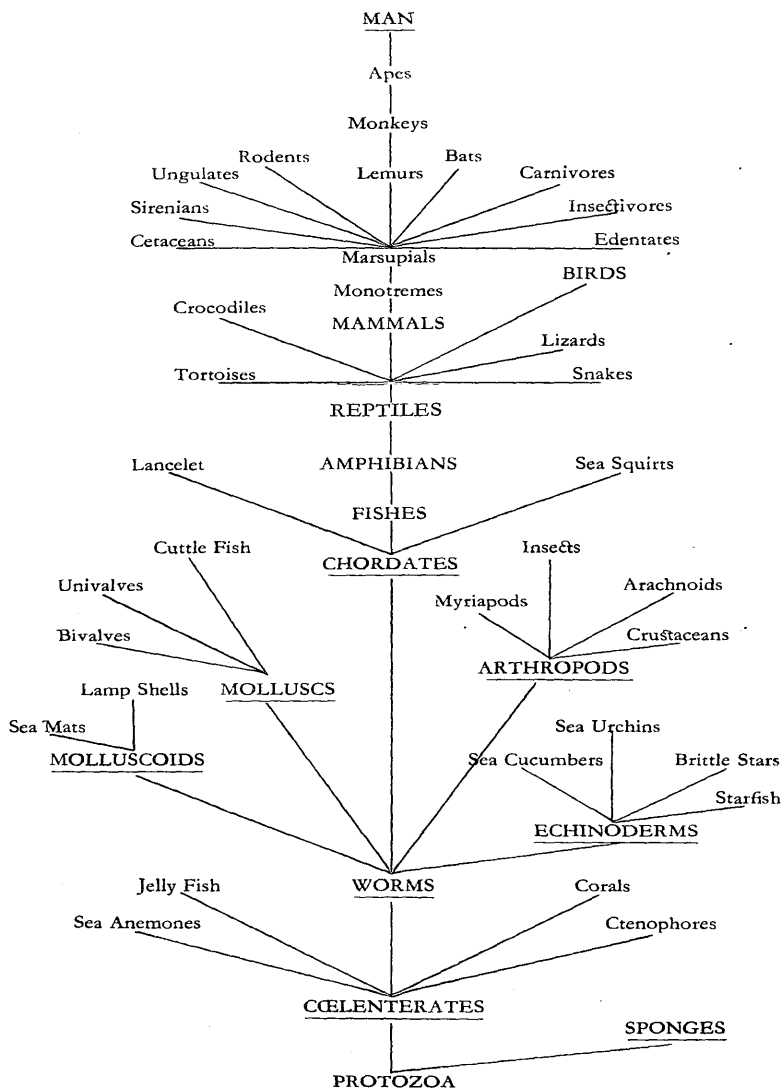


FIG. 1.

Among the principal groups the Chordates undoubtedly occupy the foremost place. They are distinguished from the rest by their possession, at some time or another in the course of their life-history, of a rodlike structure running up nearly the entire length of their bodies, and known as the *Notochord* or *Chorda dorsalis*, from which indeed they derive their name. In most cases—the Amphioxus and the Sea-squirts being about the only exceptions—this rodlike structure becomes transformed afterwards into the *vertebral column* or backbone, which accounts for their older name of Vertebrates.

Further, if a cross-section be made of a Chordate passing, we will say, through the region of the chest from the dorsal to the ventral side, the order in which certain of the principal structures will be seen is as follows: (1) The main axis of the Nervous System, as represented by the Spinal Cord; (2) the Notochord, or what afterwards replaces it, viz. the Vertebral Column; (3) the Food Canal; and (4) the Heart, or chief Blood-vessel. On the other hand, in any animal belonging to a group lower than the Chordates, not only will Notochord and Vertebral Column be wanting, but the order of the three other structures will be reversed.

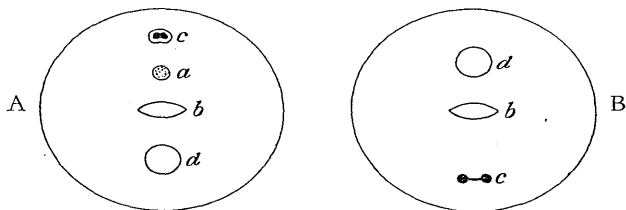


FIG. 2.—Cross-section (diagrammatic) of A, a Chordate, and B, a non-Chordate animal. *a*, Notochord; *b*, Food Canal; *c*, Main axis of Nervous System; *d*, Heart or principal Blood-vessel.

Another distinctive feature of at least all the higher Chordates is that their digestive and respiratory canals are, for a short distance at the anterior end of the body, merged into a single tube. This is represented in ourselves by the pharynx, which comes immediately behind the uvula,

and through which passes both the food on its way to the stomach and the air on its way to the lungs.¹

Once more, the Chordates, with the exception of the lowest forms, possess an internal skeleton, which is either cartilaginous or bony; and they are generally provided with two pairs of limbs, but never with more.

They are divided into five principal classes, which may be distinguished as follows:—

1. *Fishes*.—Breathe air dissolved in water by means of gills. Cold-blooded. Heart 2-chambered, but in the Dipnoi or Mud-fishes there are signs of still further division. Limbs represented by 2 pairs of lateral fins. Surface of body covered either with bony plates or with scales.

2. *Amphibians*.—Breathe at first with gills like fishes, that is, when in the tadpole stage, but afterwards with lungs. Cold-blooded. Heart 3-chambered. Limbs represented by legs. Surface of body naked.

3. *Reptiles*.—Breathe with lungs. Cold-blooded. Heart as a rule 3-chambered, but 4-chambered in the Crocodiles. Aortæ, *i.e.* chief outgoing blood-vessels, two in number, a right and a left. Limbs represented by legs, but in the Snakes aborted. Surface of body covered with bony plates or with scales. Young hatched from eggs.

4. *Birds*.—Breathe with lungs. Warm-blooded. Heart 4-chambered, with a single aorta arching over to the right. Hind limbs represented by legs, but fore limbs modified into wings. No diaphragm. Surface of body covered with feathers, but scales on the legs. Bones hollow, filled with air. Young hatched from eggs.

5. *Mammals*.—Breathe with lungs. Warm-blooded. Heart 4-chambered, with a single aorta arching over to the left. Limbs represented by legs, but in the higher apes and in Man the fore limbs modified into arms. A diaphragm divides the thorax from the abdomen. Surface of body covered with hairs. Bones filled with marrow. Young, except among the Monotremes, brought forth alive, and provided by their mothers with milk.

As to the Invertebrate or Non-Chordate divisions of the

¹ See fig. 9, p. 102.

Animal Kingdom, the following remarks will perhaps suffice :—

The bodies of the *Segmented Worms* and of the *Arthropods* are composed of a number of ringlike divisions succeeding one another from head to tail, well seen, for example, in a centipede or a lobster.

In the *Arthropods* the pairs of legs or of other appendages attached to these ringlike divisions are always jointed. The Crustaceans and Myriapods have several pairs of legs, the Arachnids four pairs, and the true Insects only three, that is, when they have reached the perfect or adult stage.

The *Molluscs* and *Molluscoids*, not being possessed of the said ringlike divisions, are perhaps descended from the Unsegmented Worms. The cuttle-fishes excepted, they have for the most part enclosed themselves in hard shells.

The *Enchinoderms* may also perhaps be descended from the Unsegmented Worms, or, if not, from the Cœlenterates. They generally present a more or less radiate disposition of parts, as is well seen in the starfish.

The *Cœlenterates*, which are certainly much lower down than any of the above, possess no proper body cavity, and instead of a food canal have simply a food sac, provided with a mouth, it is true, but with no through passage.

The *Protozoa* are for the most part microscopic organisms, each consisting of a single cell, or, if of several cells, they are practically all alike.

In each of the higher groups not only are the animals many-celled, but their cells have become differentiated in various ways, *e.g.* into muscle, nerve, cartilage, and bone cells, etc. Hence, in contrast to the Protozoa, they are collectively described as *Metazoa*. For the meaning of the term “cell” reference may be made to Chapter XIII.

CHAPTER III

LIFE AND ENERGY

WE have seen in the preceding chapter (paragraph 2) that all living things are characterised by the continually sustained harmonious working of their several parts. But we have also seen (paragraph 6) that for the maintenance of these activities energy is needed, and that this has somehow to be supplied to every organism from without. Energy accordingly plays a very important rôle in the general economy of life, and we may well, therefore, devote a special chapter to its consideration. Moreover, what has just been said applies equally to ourselves as to all the lower forms of life. Apart from the energy which we are continually receiving through our food, not only would our internal organs be powerless to perform their proper functions, but all our external activities of whatever kind would be impossible. We could move neither our hands nor our feet ; we should be quite incapable of speech ; and seeing that in our present state all our mental processes are undoubtedly accompanied by certain physical changes having their seat in the brain, these also would be brought to a complete standstill. Thus everything in the way of human achievement, including the carrying into effect of those moral decisions by which alone moral character can be built up, is conditioned by the stern necessity we are under of first obtaining, and then utilising, the energy which exists outside of us, and which is always ultimately derived from the inorganic world.

Now in the inorganic world energy manifests itself in a considerable variety of forms. There is, first, the energy of a body which is visibly in motion, such as a falling stone, a flying bullet, or a revolving wheel. Its amount can be

accurately measured, and depends partly upon the weight¹ of the moving body and partly upon the speed with which it moves. Heat is another form of energy, and consists of the intensely rapid, but invisible motions of the *Molecules*, *i.e.* of the minute particles of which all matter, whether solid, liquid, or gaseous, is composed. I may observe in passing that their minuteness is such that they lie altogether beyond the range of the most powerful microscopes. It has been estimated, for example, that in the case of hydrogen no fewer than 117 millions of them would be required to cover a line a single inch in length.² A third form of energy is that of the electric current, and once more there is the energy which day by day reaches us wrapped up in the rays of the sun.

The next important fact in connection with energy is that it can be both transferred and transformed. It is transferred, for example, when on a billiard table the motion of one ball is communicated to another, or when the heat of a furnace is communicated to the water in a boiler. It is transformed, that is to say, changed from one of its manifestations into another, when, as in a steam-engine, heat is converted into mechanical motion, or when, as in a dynamo, mechanical motion is converted into electricity. Contrariwise, electricity can be reconverted into mechanical motion by means of an electric motor, and mechanical motion can be reconverted into heat as in the primitive method of obtaining fire by rubbing together two pieces of wood. In all these changes, however, there is neither loss nor gain, for, according to the principle of the *Conservation of Energy*—one of the most brilliant generalisations of last century—energy itself, just like matter, can neither be created nor destroyed. Whatever transferences or transformations it may undergo, the total quantity of it in the Universe, so far at least as our present knowledge extends, remains unaltered.³

To avoid misunderstanding, however, the above statement

¹ More correctly the "mass."

² John Mills, *Within the Atom*, p. 200.

³ Quite recently, however, it has been suggested that a transformation of matter into energy may be taking place in the stars. See p. 406.

requires a little further elucidation. In addition, then, to those forms of energy which I have already mentioned and which are generally described as *kinetic*—seeing that they all imply some sort of real movement—there are others which are described as *potential*.

We have an excellent illustration of what is meant by the term “potential” in the case of a clock. By winding it up we communicate to it, of course, a certain amount of energy, and this energy immediately, as a rule, begins to reappear in the movements of the wheels and of the other parts. But, needless to say, having wound the clock up we are not obliged to set it going at once ; we can wait, if we choose, several hours or even days before doing so. In that case, however, if the principle of the Conservation of Energy is, as asserted, always true, what, it may be asked, has become of the energy during the interval, seeing that apparently it has gone quite out of existence ? To this the answer given is that during the interval it has become locked up, so to speak, in the suspended weights. Though the weights hang motionless inside the clock case, they have nevertheless, as the result of the winding, acquired a certain *Energy of Position*—an energy which at any moment can be retransformed into kinetic energy by releasing the pendulum and causing it again to swing. Moreover, the energy so reappearing will be exactly the same in amount as it would have been if there had been no interval at all ; none of it will have been lost. A similar illustration is afforded by a watch, except that in a watch the potential energy resides in the coiled-up spring instead of in the raised-up weights. The essential point, however, to be borne in mind is that it is only true of energy, that it can neither be created nor destroyed, when we take into the reckoning all the potential as well as all the kinetic forms which from time to time it assumes. It is the sum-total of these which, in spite of all changes, remains the constant quantity.

Now there is one particular kind of potential energy which in its relation to our present subject is of far greater importance than any of the rest. It is that particular kind which is conveyed to us in our food and which afterwards

becomes transformed into bodily heat, muscular movements, nervous currents, and so forth. But to understand the subject properly we must make a brief excursion into the realm of chemistry, and learn something of what is known about the constitution of matter.

Matter, as I said just now, is composed of myriads of minute particles called molecules, but I have now to add that each of these in its turn is composed of a number of still smaller particles called *Atoms*.¹ Of these there are, it is supposed, ninety-two different kinds corresponding to as many different kinds of simple substances, viz. those known in chemistry as the *Elements*.² The majority of them are *Metals*, such as iron, copper, lead, zinc, mercury and tin; but there are others, the so-called *non-Metals*, of which oxygen, hydrogen, nitrogen, carbon, sulphur and phosphorus may be taken as examples. Of these, including both metals and non-metals, there are some fourteen which enter into the composition of the bodies of plants and animals. Subjoined I give a list of them, inserting after the name of each the letter or letters which are generally employed to indicate them.

I. NON-METALS

1. Gases without colour, taste, or smell.

Oxygen	O.	Supports combustion; substances burn brightly in it.
Hydrogen	H.	Burns with an extremely hot, non-luminous flame.
Nitrogen	N.	Neither burns nor supports combustion.

2. Pungent, suffocating gases.

Chlorine	Cl.	Greenish-yellow.
Fluorine	F.	Colourless, very corrosive, attacks glass.

¹ There are some substances, however, the molecules of which consist of one atom only.

² There are ninety elements known at present, but it is believed that there are two more awaiting discovery, which will bring the number up to ninety-two.

3. Solids at ordinary temperatures.

Carbon	C.	Black, or as in diamond, transparent.
Sulphur	S.	Pale yellow, crystalline.
Phosphorus	P.	Waxy, translucent, highly inflammable.
Silicon	Si.	Dark brown.

II. METALS, ALL SOLIDS

Iron	Fe.	White when perfectly pure.
Calcium	Ca.	Pale yellow ; burns, forming quicklime.
Magnesium	Mg.	Silvery white ; burns, forming magnesia.
Sodium	Na.	} White, very soft, catching fire on contact with water.
Potassium	K.	

Now in the case of an elementary substance, such as any of the above, we have reason to believe not only that all its molecules are alike, but that each molecule is composed of only those atoms which are peculiar to it. In a mass of oxygen, for example, each molecule consists of a pair of very closely united oxygen atoms, and may therefore be represented by the symbol O_2 . Similarly the molecules of hydrogen and nitrogen may be represented by H_2 and N_2 respectively. In ordinary atmospheric air, which is in the main a mixture of oxygen and nitrogen, we have present, of course, molecules of both kinds, and the same may be said of a mixture of oxygen and hydrogen. Let, however, a flame be applied to the latter and an explosion will at once occur with considerable evolution of heat, and the two gases will unite to form water,¹ the properties of which differ entirely from those of either oxygen or hydrogen. Not only so, but it can be shown that the atoms have completely rearranged themselves, with the result that all the original molecules have been replaced by water molecules, each of which consists now of one atom of oxygen and two of hydrogen. Water, therefore, or rather each of its molecules, may be represented by the symbol H_2O . In

¹ It is assumed in this experiment that the two gases are mixed together in the right proportion, viz. 1 volume of oxygen to 2 volumes of hydrogen. If either gas should be in excess, the excess amount will not enter into the combination, but will remain over after the explosion.

the accompanying diagram I have tried to illustrate the nature of the change which has occurred.

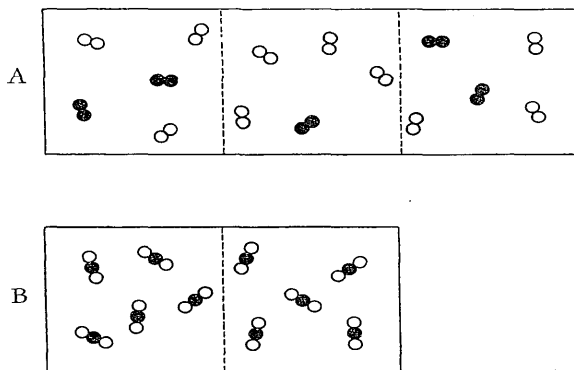


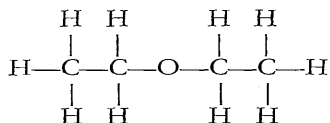
FIG. 3.—A. A mixture of oxygen and hydrogen ; B. The same gases after they have chemically united to form water. The black circles denote oxygen atoms, the white ones hydrogen atoms. Note that the three volumes have contracted into two volumes.

Water, however, is only one out of an immense number of other substances generally known as *Chemical compounds*, in which the elements composing them have become very intimately united. They are distinguished from ordinary mixtures as follows : (1) Their molecules are always made up of atoms of two or more different kinds, the number of atoms of each kind being in each case definitely fixed ; (2) their properties, as a rule, are quite different from those of the elements entering into their composition ;¹ and (3) in their formation there is often a liberation of considerable quantities of energy in the form of heat, as also when large and highly complicated molecules are being broken up and resolved into simpler ones. Again, in the building up of complex molecules out of simpler ones considerable quantities of energy have frequently to be expended.

Among well-known chemical compounds I may mention

¹ Thus that extremely pungent, highly soluble gas known as ammonia (NH_3) is a compound of nitrogen and hydrogen, neither of which possesses any smell, and neither of which is soluble in water beyond a slight extent.

the following, giving in each case the symbol which represents its molecular constitution: carbon dioxide (also known as carbonic acid), CO_2 ; ammonia, NH_3 ; common salt, NaCl ; common soda, Na_2CO_3 ; saltpetre, KNO_3 ; sulphuric acid, H_2SO_4 ; chloroform, CHCl_3 ; alcohol, $\text{C}_2\text{H}_6\text{O}$; and ether, $\text{C}_4\text{H}_{10}\text{O}$. The last of these symbols informs us, for example, that every molecule of ether contains 15 atoms, viz. 4 of carbon, 10 of hydrogen, and 1 of oxygen. Further, we have reason to believe that these 15 atoms are linked together thus :

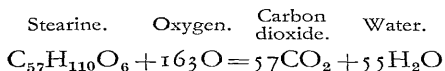


There are other compounds, however, the molecules of which are far more complicated than any of the above, as, for instance, sugar, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$, with no less than 45 atoms to each molecule; stearine, $\text{C}_{57}\text{H}_{110}\text{O}_6$, with no less than 173 atoms to each molecule; and lastly starch, the constitution of whose molecules is stated to be $\text{C}_{1200}\text{H}_{2000}\text{O}_{1000}$.¹ And yet these starch molecules are so minute as to be quite invisible under the strongest magnification.

Now it is precisely compounds like the above, with this highly elaborate molecular structure, which go to make up by far the greater part of the bodies of plants and animals. That is why they are so often described as *organic compounds*. Also they invariably contain carbon, and, as a rule, oxygen and hydrogen as well. The other elements entering into their composition are those indicated in the list given above. Contrary, too, to what is generally found in the inorganic world—among minerals, for instance—the molecules of these organic substances are extremely unstable, and are apt on very slight provocation to break up into much smaller ones. This is partly because of their unwieldy size, and partly because the chemical forces holding their carbon atoms together are, comparatively speaking, feeble. For the

¹ Starling, *Principles of Physiology*, p. 69.

same reasons they are liable to undergo various internal changes—atomic rearrangements, that is—many of which are essential to some of the most important processes of life. Again, the molecules of these substances are singularly open to the attack of oxygen, which, once give it the chance, will pounce upon them with peculiar avidity and rend them in pieces, getting hold of all the carbon atoms and uniting with them to form carbon dioxide (CO_2), and getting hold of all the hydrogen atoms and uniting with them to form water (H_2O). For example, a single molecule of stearine, which is an important constituent of fat, will be broken up under this treatment into 112 fragments, viz. 57 molecules of carbon dioxide and 55 of water. To accomplish this work of disintegration exactly 163 additional atoms of oxygen will be required, as shown in the following so-called chemical equation :—



in which the left-hand side represents the state of things previous to the reaction, and the right-hand side the state of things afterwards. It should be particularly noted in the above that the number of the atoms belonging to each element is exactly the same on both sides of the equation. In other words, there has been neither a creation nor a destruction of atoms, but only a rearrangement of them. Plainly, however, a chemical reaction of this kind cannot take place without producing a very violent commotion among the molecules, as they jostle each other, fly into fragments, and their fragments rush together to form new combinations. Now it is precisely this violent commotion on their part which is the source of those peculiar molecular vibrations generally spoken of as heat. In fact, what has just been described is simply one instance out of many of what is commonly known as combustion, whether it occurs rapidly as in the burning of fuel in our grates, or much more slowly as in the burning of our food which is continually going on inside our bodies. In either case—and

this is the important point to which I have been leading up—there is a conversion of potential into kinetic energy. For just as a raised weight possesses potential energy, because on yielding to the attractive force of the earth (gravity) it can produce mechanical motion, so these substances to which I have referred, with their extremely complicated molecular structure, also possess potential energy, because on yielding to the attractive force of oxygen (chemical affinity) they can produce heat, or some other equivalent form of energy.

Lastly, to apply all this, it has been conclusively shown that the kinetic energy needed for the carrying on of all the manifold processes of life, whether in animals or plants, is entirely derived from the potential energy locked up in these highly complicated molecules, which are so inconceivably small, however as to lie altogether beyond the reach of our present senses. And this result appears all the more marvellous, when we think of it in its relation to ourselves, and how it means that every form of human activity, from ordinary manual labour up to the working of the brain, say, of a Newton or a Shakespeare, has for its foundation that which lies hidden deep down in the very constitution of matter.

But if life, as we know it, is thus wholly dependent on the existence of these energy-containing, highly complex molecules, it is equally dependent upon the existence of oxygen, which, by breaking up the molecules, releases the energy contained in them. Consequently all living things, plants and animals, including ourselves, must not only eat but breathe—that is, take into their systems free or uncombined oxygen.

And here arises another interesting point. Vast as is the supply of oxygen available for breathing purposes—no less than 23 per cent. of the total weight of the atmosphere consisting of it—it is a singular fact that it forms after all only a very small proportion of the entire amount which must originally have been present on our planet. Enormous quantities of it entered long ago into practically indissoluble union with the various other elements found in the earth's

crust, and hence became quite useless so far as breathing purposes are concerned. Other enormous quantities of it became similarly useless by entering into union with hydrogen to form the waters of our oceans, seas, rivers and lakes.¹ According to a rough computation, the amount of oxygen locked up in these waters must be nearly a thousand times greater than the amount of free oxygen contained in the atmosphere. The latter, therefore, may be regarded as the comparatively insignificant residuum which by a kind of accident (?) remained over after the greater part of the original oxygen had been used up in other ways.² And yet it is on this comparatively insignificant residuum that all organisms are compelled to draw for the carrying on of those respiratory processes which are so necessary to their existence—a truly remarkable fact, for taken in conjunction with others, to which I hope to refer later on, it shows us that Life has insinuated itself into the general structure of our world by only the narrowest of loopholes, and by taking advantage of a very singular combination of circumstances.

In conclusion, there are two questions which may very pertinently be asked in reference to the highly complicated chemical substances which we have been considering. The first is, How are we to account for their universal presence in the bodies of animals and plants, when in the purely inorganic world there is practically no trace of them? And the second question is, How has the potential energy stored up in these substances been obtained, seeing that it has most certainly not been derived from either the earth's atmosphere, its waters or its soils, although animals and plants alike are continually having recourse to these last for their building materials? But the two questions are inseparably bound up with one another, as we shall have occasion to see in the next chapter.

¹ Oxygen forms 48 per cent. by weight of all limestones (CaCO_3), 53 per cent. of quartz and sand (SiO_2), and 88 per cent. of water (H_2O).

² See also Chapter XXVIII, p. 418.

CHAPTER IV

ANIMAL AND VEGETABLE LIFE

IN Chapter II we have already considered the chief characteristics which mark off living organisms from lifeless things. In the present chapter we shall consider those which mark off animals from plants. Now, although in the vast majority of cases there is no difficulty in deciding to which of the two great Kingdoms of Life a given organism should be assigned, the difficulty does arise in connection with some of the lowest forms. The beautiful little *Volvox*, for example, which is green in hue and measures only about $\frac{1}{50}$ th of an inch in diameter, has been described sometimes as an animal and sometimes as a plant.¹ Nor is this altogether surprising, seeing that like an animal it moves about in the water with considerable vivacity, and that like a plant its greenness is due to the presence in it of *Chlorophyll*, a substance which, as we know, plays a most important and highly characteristic part in the life of plants.

Moreover, if we could go back far enough into the geological past, we should probably come to a time when animals and plants were indistinguishable from one another, such organisms as existed then partaking more or less of the characteristics of both.² With the progress of Evolution, however, and with the coming in of continually higher forms, a gradual divergence appears to have taken place, according as the animal or the vegetable tendency predominated. The consequence is that with comparatively few exceptions, of which the *Volvox* is a case in point, the innumerable species of organisms which people the earth

¹ Bourne, *Comparative Anatomy of Animals*, vol. i, p. 72; Vines, *Students' Textbook of Botany*, p. 238.

² It has been conjectured that many of the original organisms were akin to bacteria. See Dendy, *Outlines of Evolutionary Biology*, pp. 217, 218.

to-day may at once be classed as belonging to either the Animal or the Vegetable Kingdom.

As to the two tendencies just referred to, it is important to observe that the tendency of the animal has been all along towards ever-increasing activity, whereas the tendency of the vegetable has been towards a fixed, a sedentary kind of life. While the industrious animal was gaining more and more facility in moving about and was thereby constantly putting itself into new and still more complex relations with the Universe outside, the unenterprising vegetable went and permanently rooted itself in the soil. And this distinction must be regarded as a fundamental one, in spite of the fact that some plants possess powers of locomotion, and that some animals, having travelled a certain distance along the upward path of development, have turned backwards, encasing themselves very often in hard, cumbrous shells, or else becoming parasites inside the bodies of others, their so-called *hosts*. It must be remembered, too, in the case of plants that, although they have betaken themselves to a comparatively sluggish kind of existence, they have not given up activity altogether. The very fact that they can grow, shooting up their branches high into the air and unfolding their buds into leaf and blossom, implies activity of some sort, as does also the ascent of sap in their roots and stems, not to mention the many elaborate chemical processes which go on in their various tissues.

But although the distinction between animals and plants turns very largely on the question of their greater or less degree of activity, the subject is one into which we must go a little more deeply. Now, as we have already seen in the preceding chapter, neither plants nor animals would be capable of any activity at all unless they were somehow supplied with energy. And, as we have also seen, the energy with which they are actually supplied is of that peculiar potential kind locked up in those highly complicated carbon compounds, which on combustion with oxygen yield heat and mechanical motion. But here comes in a most important difference as between animals and plants.

For whereas animals obtain these compounds exclusively from the food which is furnished them by plants,¹ plants, with the exception of the fungi and of certain other more or less parasitic forms, construct these compounds for themselves, manufacturing them out of a few very simple ingredients, viz. the carbon dioxide which they absorb from the air, and the water with its dissolved salts which they absorb from the soil. None of these last-mentioned substances, however, all of which are derived from the mineral world, possesses any potential energy in itself. You cannot burn and so get energy out of either carbon dioxide (CO_2), water (H_2O) or soil, inasmuch as their molecules already contain as much oxygen as they are capable of combining with. Consequently, the potential energy which comes to be stored up afterwards in the aforesaid carbon compounds must be derived from some other source. Now this source has been conclusively shown to be the kinetic energy which in quite unlimited quantities is daily reaching the earth bound up in the rays of the sun. Utilising this energy, plants are able to tear asunder the carbon and the oxygen atoms, which in their union with one another form the molecules of carbon dioxide (CO_2) supplied by the air. Next, with these carbon atoms and with the oxygen and hydrogen atoms obtained from the water (H_2O) sucked up by their roots, they construct, first, the complex molecules of starch ($\text{C}_{1200}\text{H}_{2000}\text{O}_{1000}$), and afterwards the molecules of all the other organic compounds which they require. In this process the kinetic energy of the sun's rays becomes transformed into the potential energy contained in the new substances just mentioned, and is ready, therefore, to be retransformed into the kinetic energy of heat and of muscular movements, etc., whenever these substances are subsequently taken in by animals in the shape of food.

Hence the three following propositions may be laid down. First, animals are wholly dependent upon plants for their existence, seeing that all the energy at any time displayed by them has been got out of the food with which they have

¹ Flesh-eating animals form no real exception to this, for the animals they feed on nearly always draw their sustenance from plants.

been provided by plants. Secondly, the entire energy displayed by both animals and plants is in the last resort to be traced back to the energy of the sun's rays. And thirdly, whereas plants are the great storers up and conservators of energy, employing afterwards only a very small fraction of it for their own purposes, animals are its great squanderers, using it up in the most lavish way in the performance of their numerous and often exceedingly vigorous movements. And these movements have become all the more numerous, all the more vigorous, as the great Evolutionary Process has gone forward, and higher and still higher types of animal life have appeared.

Now what do we gather from all this? We gather that the divergence between the Animal and the Vegetable Kingdoms, which must have occurred in very early geological times, was absolutely necessary if Life was at last to manifest all that wonderful exuberance of activity, which is so striking a feature of the higher animal forms. The leap of the fish in the pool, the gallop of the horse across the plain, and the swoop of the eagle on its prey, would alike have been impossible if that divergence had not taken place, and if plants had not set themselves the task of laboriously extracting from the solar beams the energy which was afterwards to be expended, and in such unstinted fashion, in the production of all the multifarious animal movements.

But this being so, we seem almost compelled to put the question, Was the divergence which took place a merely accidental thing, or may we recognise in it something more, viz. the expression of a definite purpose on the part of some unseen presiding Intelligence? Did the latter ordain that the onward-flowing River of Life should divide itself almost from the first into these two distinct streams, in order that, as we shall see later on, it might issue at last among other things in certain very important and far-reaching consequences in Man? Or are we to resign ourselves to the thought that what happened was merely a matter of chance, a thing blindly stumbled upon, and which might so easily, therefore, have never happened at all? ¹

¹ See Additional Note at end of the chapter.

But to proceed, there are a few other points of considerable interest in connection with the general subject of this chapter to which I must allude.

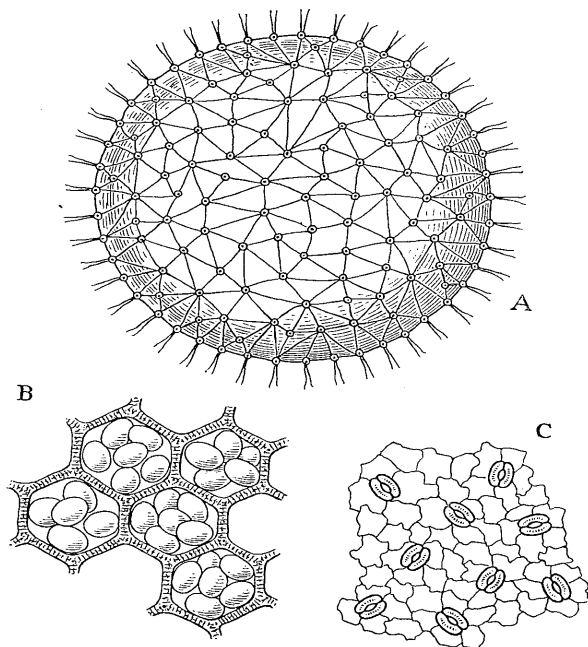


FIG. 4.—A. Volvox ; B. Part of a Moss leaf, showing cells with enclosed chlorophyll bodies ; C. Under surface of a leaf, showing stomata, each surrounded by two guard-cells.

And, first, the power which plants possess of extracting carbon from the carbon dioxide of the air has been proved to reside in their green parts only, and more particularly in their leaves. If we examine any leaf under the microscope, we shall find that its colour is entirely due to the presence in it of a vast number of minute, green-coloured granules, the so-called *chlorophyll bodies*. They are usually round or oval in shape, and can most easily be seen in the

leaf of a moss. In *Mnium hornum*, for example, a quite common species, they measure on an average about $\frac{1}{1000}$ th of an inch in diameter. Now the importance which attaches to these little granules lies in the fact that they and they alone are the instruments by means of which plants lay hold, so to speak, of the sun's energy, and store it up in the manner above described. Hence it is to the agency of these minute chlorophyll bodies that the entire animal world, including ourselves, ultimately owes all its activity, and therefore its very life—a consideration which surely places them among the most interesting little objects in Nature.

Again, the presence in plants of these remarkable little bodies would be of no use at all, unless there were a sufficient supply of carbon dioxide available in the surrounding air. Strange, however, as it may seem, in view of its extreme importance in reference to life, carbon dioxide forms only about $\frac{1}{2500}$ th of the total bulk of the atmosphere.¹ And yet it is on this quantity comparatively so small, that plants, and by their means animals as well, have to depend for their very existence, inasmuch as carbon is absolutely essential to them, and there is no other source except the atmosphere from which it can be obtained. But this is simply another illustration of what I remarked upon before, that Life has only gained entrance into, and found a firm footing on, our planet by the narrowest of loopholes, and by taking advantage of what would appear to be a most singular combination of circumstances.

Animals feed upon plants, plants feed upon minerals, or rather upon mineral substances—a difference which, as we have next to see, has exerted a most profound influence on the general forms which they have respectively assumed. And here the fundamental fact to be borne in mind is that the amount of vegetable food available for animals exists in nothing like the same profusion as the mineral food available for plants. Given suitable climatic conditions and a favourable soil, a plant will grow up and thrive vigorously in the same spot for many years, perhaps centuries, and will find no difficulty in obtaining from the air

¹ Roscoe and Schorlemmer, *Treatise on Chemistry*, p. 449.

above and from the soil beneath all that it needs in the way of nourishment. It is otherwise, however, with the majority of animals. Not only is their supply of food strictly limited, but they have somehow to get hold of and consume very considerable quantities of it, if they are to secure all the energy they need for their far more active mode of life. Tethered to a single spot, an animal would speedily exhaust whatever supplies of food might lie within its reach, and would consequently before long die of starvation. Hence we see how imperative it is that animals should be able to move about in search of their food, and that for this purpose they should be provided with those special organs of locomotion which form, as we know, one of their most distinctive features. Thus legs gradually arose for walking, running, and leaping, wings for flying and fins for swimming, while among the lower, the invertebrate tribes, there were evolved—to quote just a few examples—the hairlike cilia of such little organisms as the *Volvox*, the finger-like tentacles of the *Sea-anemone*, and the curious so-called tube-feet of the *Starfish*. Now all these locomotory appendages owe their origin to the basic fact that, because of the relative scarcity of their food, as compared with that of plants, animals were compelled to go in search of it.

But other results have followed from the same cause. For instance, whereas plants, in order to get all that they can out of their immediate surroundings, have been obliged to go in for an extensive system of branching, as is evidenced by both their stems and their roots; animals, just because they are not tied down to a single spot, have had no need to do so. Instead, they have found it to their advantage to possess bodies so shaped, that the medium in which they naturally live should offer the least possible resistance to their movements. We have an excellent illustration of this in the case of fishes, which with their smoothly polished surfaces and with their beautifully curved forms are so admirably adapted for progression through water. Moreover, to prevent unnecessary friction a fish swims end-on, not sideways; and its two sides are exactly alike in shape,

inasmuch as any irregularity in this respect would deflect it in its onward course. Accordingly a fish is said to be *bilaterally symmetrical*, which means that there is just one way in which it can be divided into two equal and precisely similar halves, viz. by a section passing vertically through it from head to tail. Bilateral symmetry, I may add, characterises nearly all the higher animals, viz. amphibians, reptiles, birds, and mammals, all of which are supposed to be descended from fishlike ancestors. It will not escape notice, too, that with scarcely an exception every one of our artificial contrivances for getting about is constructed on the same principle. All our sea-going vessels and lesser craft are bilaterally symmetrical, as also are our land vehicles of every description, from the express train down to the bicycle and the child's perambulator, not to mention those still more modern inventions, the airship and the aeroplane.

Again, as nearly all plants are firmly attached to the soil and are practically incapable of self-movement, they are compelled to take in their food at a great number of different points. To this end the under surfaces of their leaves, and sometimes their upper surfaces as well, have been covered over with *Stomata*, which are numerous minute mouth-like orifices, for the passage inwards of the carbon dioxide and for the passage outwards of aqueous vapour, etc. Thus it has been estimated that in a blade of grass there are no less than 20,000 of them to every square inch. Among animals, on the contrary, if we omit perhaps the sponges, a single mouth has been found sufficient, seeing that by means of locomotory and other accompanying movements it can so easily be applied to whatever food may come within reach. Again, the mouth is nearly always situated at the anterior, or head end of the body, so that, as the animal goes forward, its food may the more readily be seized. Further, as it would be of little use to be provided with either mouth or locomotory organs, unless animals were somehow guided in their search for food, and were made aware of the direction in which to go for it, they have been endowed with those special senses—hearing, sight, and smell—which enable them to penetrate, so to speak, their

immediate environment, and to recognise objects at a greater or less distance off. Once more, the organs of these special senses—the ears, the eyes, and the nostrils—have been placed like the mouth at the anterior end of the body, as that is the position, of course, in which they can be of most service ; and lastly, and very closely connected with this, there is the arrangement by which the main mass of the nervous system, or brain, has been developed in the same general region, namely, the head.

Thus the external configuration of the bodies of the higher animals, their bilateral symmetry, their possession of organs of locomotion and of organs of special sense, together with the positions of these and of the single mouth and of the brain, have all been determined by the necessity imposed upon animals of being forced to go in search of their food. And they have been forced to do so, because otherwise—such are the conditions of life prevailing on our planet—they would not have been able to obtain enough of the needful food and therefore of the needful energy for the exercise of those wonderful activities, which in so striking a manner distinguish them from plants.

SUMMARY

1. Animals and plants are probably descended from certain minute primitive forms which must have partaken more or less of the characters of both.

2. Animals differ primarily from plants by the exercise of certain superior activities.

3. They would not be able to exercise these unless they were supplied with the requisite amount of energy.

4. This energy is supplied to them by plants, being locked up in potential form in those highly complicated carbon compounds which they receive from plants in the shape of food.

5. To turn this energy to account—to change it into bodily heat, muscular movements, and nervous currents, etc.—these compounds have first of all to be consumed, to be resolved, that is, into much simpler compounds, such

as carbon dioxide and water. But for this purpose free oxygen is required, which all animals therefore are compelled to breathe.¹

6. As though it were for the express purpose of enabling animal life to exist and to continue developing into higher and still more active forms, plants have had the special task assigned them of building up the aforesaid energy-containing compounds.

7. The energy in these compounds is entirely derived from the solar rays, and hence the sun is the ultimate source of all animal activity whatsoever.

8. Seeing that the food required by animals, unlike that required by plants, is not to be found everywhere, but is strictly limited in amount, animals have been compelled to go in search of it.

9. To enable them to do so, Life has again, as of express purpose, provided them with the necessary locomotory and sensory organs, and in a number of other ways adapted them for the special rôle which they have been called upon to play.

Additional Note.—If, according to the late Professor Lowell, the greenish-grey areas on Mars are indicative of vegetable life, and if some day it should be definitely proved that animal life exists there also, it would supply us with another instance of the same kind of divergence having taken place. This would make it still more difficult to believe that such divergence could be the mere result of chance.

¹ Plants also breathe, but to nothing like the same extent.

CHAPTER V

LIFE AND PURPOSE

IN the account given in the preceding chapter of the relations existing between plants and animals, I have several times employed the term "purpose." Now as the idea of purpose is going to play a very prominent part in all that is to follow, it may be as well before proceeding further to make quite sure as to what exactly we mean by it. And this becomes all the more necessary, seeing that in ordinary parlance a certain amount of ambiguity attaches to it. More particularly we have to distinguish between what may be termed its primary and its secondary meanings.

According to its primary meaning a purpose can only arise in connection with some mind which actually purposes. A mental picture, an idea, is first formed of some end more or less desirable which is to be attained ; then in most cases the successive steps are considered which will lead to its attainment ; and lastly, a series of actions are performed, extending over a longer or shorter period, till the idea as originally formed has been realised. Here, it will be observed, not only does the mental picture, the idea, precede its realisation, but it may legitimately be described as its cause, though no doubt there are philosophers who would prefer to say that it is not the mental picture itself which is the cause, but rather the particular brain state, of which it happens to be the accompaniment.

Now it is not too much to say that with scarcely any exception all our consciously directed activities are for the carrying out of purposes in the sense just described, and that, whether these purposes are of a serious or of a trivial kind, we employ most of our waking hours in the pursuit of them. The man of business, for example, who leaves

his home early every morning, walks down to his office, and on entering it goes through his correspondence and afterwards gives directions to his clerks and other assistants, is presumably, in all these varied acts of his, working for the one purpose of making his business a success and of possibly piling up for himself a big fortune. A similar remark applies to the ordinary pleasure-seeker and to the man, we will suppose, who is planning how exactly he will spend his brief but well-earned holiday. In each case the dominating fact is an idea previously entertained of some desirable end—an idea which spurs on to action, and often to a highly complicated series of actions, in order that at last the end sought for may be attained.

The end, however, need not always be clearly conceived. The geographical explorer, for instance, who is just setting out on a polar expedition may not know what important discoveries may be in store for him, and yet it is these unknown discoveries which form the real object of his pursuit. It is the same with the scientific investigator who hopes by his observations and experiments to unravel still further the mysteries of the world around him; and it is the same, too, with anyone who is trying to solve something which is in the nature of a problem.

Sometimes, on the other hand, not only will the end be clearly conceived, but it will be conceived with a considerable amount of detail, as in an architect's design for a large public building, or in an engineer's scheme for the construction of a railway through a difficult piece of country. In such cases, however, neither the architect nor the engineer will as a rule carry out his own plans and specifications. These will be left in the hands of others working under his supervision. Whenever this is so we shall have, of course, the distinction, which it will be well to bear in mind, between the originator of a purpose and those who are afterwards entrusted with its execution.

So much, then, for the primary meaning of the term "purpose," which, as we have seen, would have no meaning at all apart from some mind which actually purposes. But we often use the term in a secondary sense, applying it to

purely inanimate objects, as when we say of a clock that its "purpose" is to keep time, or of a dynamo that its "purpose" is to generate electricity. In fact there is scarcely anything made by man, from a set of gardening tools up to the most elaborate piece of machinery, which is without its purpose. Works of art too, like pictures and statuary, and such things as articles of dress and household ornaments, have likewise each a purpose to fulfil, viz. to please and to awaken certain feelings of a more or less elevated æsthetic character. But whatever may be the particular nature of the purpose when the term is used in this secondary sense, it is obvious that it is a derived sense, and that not one of the things just mentioned could be described as having a purpose unless it had been previously put into it, so to speak, by some purposing mind.

If now we turn attention to a living organism, and especially to one which stands high up in the general scale, what strikes us is not only the amazing variety and complexity of its several parts, but the way in which each part has its own distinctive function to perform, in other words its purpose, and the way, moreover, in which all these different purposes are subordinated to the one supreme purpose of maintaining in fulness of life and activity the organism as a whole. Now so long as it is understood that in this connection we are using the term "purpose" in the strictly secondary sense as just explained, no one, I imagine, would wish to quarrel with it. For, as simple matter of fact, our eyes do subserve the purpose of seeing, our feet of walking, our lungs of taking in oxygen, and so on with all the other organs of the body.

Controversy, however, arises directly we begin to go beyond this point and to inquire whether we may legitimately draw the conclusion that all the very varied, intricate, and harmoniously related purposes displayed, for instance, by the human body presuppose a Purposer, who is the unseen Source and Originator of them. Are we warranted in doing this? In other words, may we regard Paley's "argument from design," with its famous illustration of the watch, as being still of force?

Now in the opinion, no doubt, of many it is held that it lost all its force long ago, inasmuch as since Paley wrote (he died in 1805) the great Evolutionary Doctrine has come to be one of the most firmly established scientific generalisations ; and this, it is supposed, has completely undermined Paley's reasoning. But everything here depends on what precisely is meant by the Evolutionary Doctrine. If, as explained in Chapter II, paragraph 10, it simply means that all the various forms of life, both past and present, are related to one another by the ties of common descent, the higher having been derived in the course of ages from the lower, and ultimately perhaps from just a few microscopically minute organisms, then it is difficult to see why the argument from design should be affected by it. That Life on our little planet should have unfolded itself in this wonderful fashion is surely quite as much in need of explanation as it was on the former supposition, that every species of plant and animal had originated separately.

The fact is, it is not the doctrine of Evolution in itself, the theory of Common Descent, which militates against "the argument from design," but a certain theory as to the Cause of Evolution which has been combined with it—the theory, namely, which would account for the whole marvellous process by means of a number of blindly produced variations working in conjunction with what is known as *Natural Selection* or the *Survival of the Fittest*.

Now, familiar as this theory must be to most of my readers, it may be advisable here to give the essential gist of it, and especially as one of my main objects in the succeeding chapters will be to point out its inadequacy and to show how we are almost driven to the conclusion that some kind of Superior Intelligence must have been at work, invisibly directing the course of Evolution from the earliest times until now.

Although the subject will have to be discussed at greater length later on,¹ I may remark here parenthetically that, if such a conclusion could be established, there are at least three things which would at once be explained by it :

¹ Chapters XXV and XXVI.

first, why the Evolutionary Process starting from such humble beginnings should have pursued on the whole so progressive a course; secondly, why all the exceedingly complicated arrangements which we find in the higher organisms should be of so peculiarly purposive a character; and thirdly, why at the end of the Process minds such as ours should have emerged possessed of psychic powers so immeasurably in advance of any which could conceivably have belonged to those primitive forms to which we are asked to trace back our descent. But, on the other hand, let the variations in question be the result of forces entirely blind and unintelligent, and the three things just mentioned seem at first sight to be quite incapable of explanation.

How, then, does the theory which we are venturing to criticise attempt to explain them? By summoning to its aid the principle of Natural Selection which, although undirected by any intelligence, has nevertheless so brought matters about, as to make the organic world *appear* like the work of intelligence, such appearance, however, being entirely illusory.

According, then, to this theory, Natural Selection works as follows. Seeing that the reproductive process gives rise as a rule to a far greater number of offspring than can possibly grow up to maturity, it is plain that only a certain number of the variations occurring from time to time can be handed on to succeeding generations. But which variations will they be? The answer given is that they will be just those which confer some distinct advantage on the organisms possessing them, enabling them thereby to grapple more effectually with their circumstances and so to hold their own in the great struggle for existence. This will be because organisms, in which such favourable variations have arisen, will stand the best chance of reaching maturity and of transmitting them, therefore, to their offspring, whereas organisms in which unfavourable variations have arisen will be unable to transmit them, seeing that probably they will never reach maturity at all. In this way the favourable variations will alone be preserved, and these will go on accumulating, with the result that in the course

of ages animal and vegetable forms will appear with organs increasingly complex and more and more accurately adjusted to the special conditions in which they live. It is these "fittest" forms, then, which will "survive," and their survival will be due to the manner in which, as just described, "Nature selects." Thus two entirely unintelligent causes—variations of a fortuitous kind, and natural selection—will by their conjoint action produce on us the impression, quite erroneous, however, that some intelligent cause has been at work.

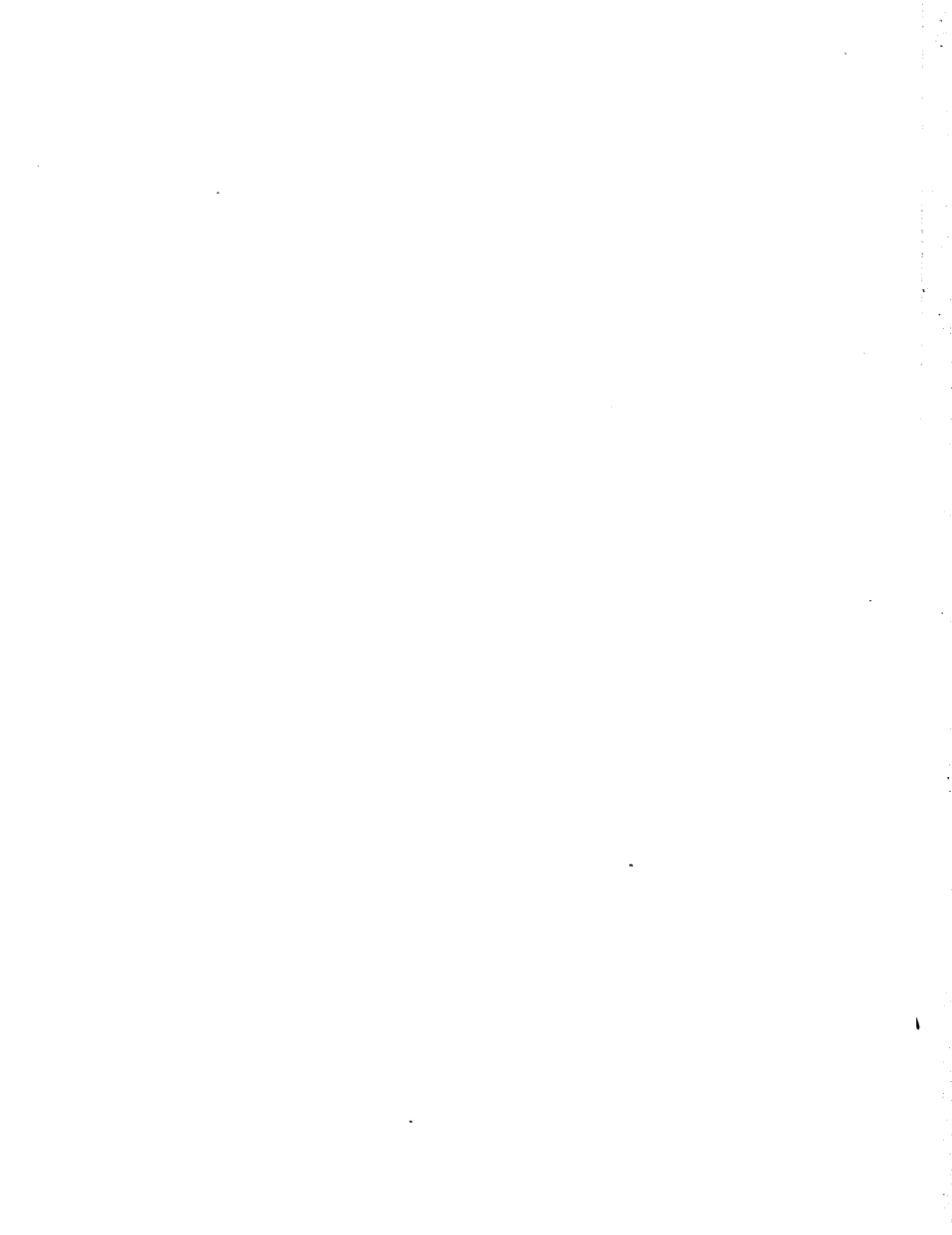
As to the sufficiency of this truly ingenious theory to account for what has happened I will venture at this stage only one remark. It is that it does seem passing strange, a thing wholly inexplicable, that an Evolutionary process which has been running its course for so many millions of years undirected by any purposing mind, should issue at last in beings like ourselves, who not only possess minds, but whose conscious activities are practically, as we have seen, all performed with a view to the accomplishment of purposes. But how on such a theory, one is constrained to ask, did purposes of any kind manage to effect an entrance into the world at all?

That variations, which may be described perhaps as fortuitous, and that natural selection have both played a certain part in the evolution of our Life-System I am by no means prepared to deny. At the same time, and for reasons which will afterwards be given, I feel convinced that their importance has been very greatly exaggerated, and that by themselves they are wholly inadequate to explain the origin of all those marvellous structures which are found in the bodies of plants and animals.¹ I propose, therefore, in the next few chapters to give a short account of some of these structures, drawing my illustrations chiefly from the human body, as being the form with which we are most familiar. In doing so my object will be not only to call attention to the special purpose which each organ subserves,

¹ "The modern geneticist assigns to Natural Selection a subordinate and inconspicuous rôle."—W. Bateson, article in *Encyclopædia Britannica* on Mendelism, vol. xxxi, p. 912, eleventh edition.

but to show how, as the result of the grouping of the various organs into systems—of which the digestive and respiratory systems may be taken as examples—each system possesses a higher purpose of its own. Further, I shall try to show how these systems in their turn are so bound up with one another, as by their concerted action to secure the three great ends after which every organism strives, viz. the maintenance of itself alive, the holding of more or less intimate relations with the environment, and the perpetuation of its own kind.

It is only, in my opinion, by entering into a considerable amount of detail in reference to these subjects that their full argumentative force can be properly realised, and that it will appear increasingly doubtful whether such an extraordinarily intricate piece of mechanism as, for instance, the human body could possibly have arisen by the operation of unintelligently produced Variations and of Natural Selection alone.



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CHAPTER VI

THE DIGESTIVE SYSTEM

As a help to the understanding of the general subject on which we are now entering, the subjoined table will perhaps be found useful. It is a classified list of the principal functions of the human body and of the several organs engaged in their performance. It shows also how these functions fall naturally into three great divisions, viz. the functions of (1) Maintenance, (2) Interaction with the Environment, and (3) Reproduction. In some cases it will be noticed that the same organ performs more than one function, *e.g.* the skin.

FUNCTIONS AND ORGANS OF THE HUMAN BODY

I. MAINTENANCE

1. *Digestion*

Organs.—(a) The Food Canal with its different sections, including the mouth cavity, the pharynx, the gullet, the stomach and the small and large intestines; (b) the Accessory Glands, viz. the salivary, gastric and intestinal glands, the pancreas and the liver.

2. *Respiration*

Organs.—The Lungs and the nasal cavities, the pharynx, the windpipe and its branches. Also the diaphragm and the chest muscles.

3. *Circulation*

Organs.—(a) The Heart with its four chambers and its valves; (b) the Arteries, capillaries and veins; (c) the Lymphatic vessels and glands; (d) the Spleen and red marrow; (e) the Blood and the lymph.

4. *Excretion*

Organs.—The Lungs, kidneys and skin.

II. INTERACTION WITH THE ENVIRONMENT

1. *Movement*

Organs.—The Muscles, tendons, bones, cartilages, joints and ligaments. The four limbs and the larynx.

2. *Sensation*

Organs.—The Eyes, ears, nostrils, palate, tongue and skin.

3. *Co-ordination and Control*

Organs.—The Brain, spinal cord and ganglia : the incarrying and outcarrying nerves. The Sympathetic ganglia and nerves.

III. REPRODUCTION

Organs.—The Ovaries and Testicles.

Beginning, then, with Digestion, the question may naturally be asked, Why should it be necessary in the case of animals, but not in the case of plants? The answer will be found by considering the different nature of their respective foods. Plants, as we have seen (Chapter IV), take in carbon dioxide from the air, and water and dissolved salts from the soil—that is, they feed upon substances which are either liquid or gaseous. Animals to a certain extent do the same, but they are obliged to take in solid substances as well, inasmuch as the energy-containing compounds, which are supplied to them by plants and which are so necessary to their life, nearly all exist in the solid or the semi-solid form. But that these may be absorbed by the body, they must be brought first of all into a state of solution, and it is in the main to accomplish this that the whole of the highly elaborate digestive system, as it is found for example in ourselves, has been gradually evolved.

Now whenever any solid substance is to be dissolved, two things as a rule are necessary, namely, a hollow vessel

of some sort in which the solution may take place, and, if water will not suffice, then some other solvent or set of solvents of the right chemical composition. In the lowest animals of all, such as the Protozoa and the Sponges, it is true no such special arrangements exist. In the Cœlenterates, however, which come next and which include the sea-anemones, the jelly-fish, and the corals, a certain sacklike cavity has made its appearance, though it possesses a single entrance only, through which the food is both taken in and such portions of it as prove indigestible are afterwards put out. But in nearly all animals higher than these the sacklike cavity has been converted into a canal open at both ends, along which the food during digestion is slowly propelled. Further, the successive portions of this canal have in the course of evolution come to assume different characters, each having to discharge some special function of its own, and so we get finally the well-known series, consisting of the cavity of the mouth, the pharynx, the gullet, the stomach, the small and the large intestines.

In the cavity of the mouth the first thing to be done is to break up the food into small fragments—to masticate it—so that the digestive fluids, or juices as they are called, may the more readily bring it into a state of solution. For this purpose teeth of various kinds have been provided for seizing, cutting, and grinding it, and, that they might be able the better to stand the constant wear and tear to which they are exposed, they have been coated with enamel, the hardest substance in the body. But, plainly, the teeth would be of no service whatever unless one or other or both of the jaws were movable. Hence in ourselves and in nearly all the Chordates the lower jaw has been made to work up and down, and to a certain extent from side to side, as also backwards and forwards. The last two movements are to enable us to grind our food; and, that we may keep it well in place while the grinding is going on, the muscles of the tongue and cheeks are likewise brought into action. In the snail and in other univalves a very curious arrangement prevails, the teeth being inserted on a sort of band—the *Radula*—which works to and

fro pulley-wise. In birds, which have no teeth, but only bills, the grinding is done lower down in the canal, in a special organ known as the gizzard, which with its strong muscular walls crushes the food, assisted by a number of little stones, which the birds by a strange instinct are in the habit of swallowing.

But we not only masticate our food in the mouth cavity ; we begin to digest it there, and to this end three pairs of glands are provided for the manufacture of saliva, which, whenever wanted, is discharged into the mouth through certain little tubes or *Ducts*. Now saliva possesses the peculiar property of converting into sugar the various starchy substances which form so important a part of our diet. Hence, sugar being soluble in water, whereas starch is not, it can quite easily on reaching the intestine pass through the membrane lining its walls and so find its way into the blood.

As to the structure of a gland—and all glands are essentially

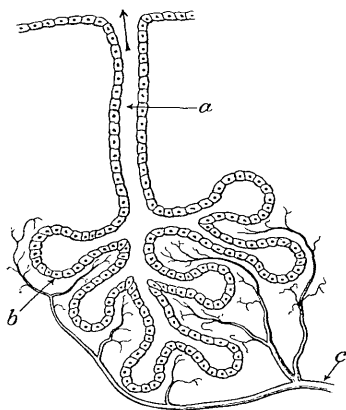


FIG. 5.—Diagram of a Gland. *a*, duct ;
b, secreting cells ; *c*, vessel and its
ramifications supplying blood.

alike—it consists of a simple, or of a more or less branched, tube surrounded by a network of minute blood-vessels, the capillaries, with which, however, it is not in direct communication—that is to say, there is no actual passage between them. One end of the tube is open and forms the duct through which the gland pours out its contents.¹ The other end is blind, or if, as is more often the case, the tube should be of the branched variety, then all the ends of the branches are blind also. Interposed between the

blood-vessels on the one hand and the tube and its branches

¹ I am ignoring, of course, the so-called “ductless glands.”

on the other are multitudes of microscopic cells,¹ which in some mysterious manner extract from the blood just the materials needed for the manufacture of the particular juice, digestive or otherwise, which it is their business to supply.

That all the juices in the body, or *secretions* as they are called, should thus be derived from the same source is surely a most remarkable fact, considering how greatly they differ from one another in their chemical composition and in their several uses. Indeed, it would seem almost as though each gland were endowed with some strange power of choice and were unconsciously seeking to fulfil its specially assigned purpose in the general economy. Even in the case of excretions, which like the urine are extracted from the blood merely to be got rid of, a purpose is still subserved, seeing that their continued retention in the body would be most injurious, and would probably sooner or later result in death.

Next to the mouth and immediately behind it comes the pharynx. Now the pharynx marks the place where the digestive canal leading down into the stomach coincides over a short distance with the respiratory canal leading down into the lungs. This arrangement is peculiar, however, to the higher animals only, viz. the Chordates,² and is one which, as we shall see later on (Chapter IX), has led to certain consequences in man of a highly interesting and important kind. The arrangement being such as it is—the nasal passages and the mouth cavity opening into the pharynx above, and the windpipe and the gullet opening out of it below—special precautions had to be taken to prevent the food in its downward course from going the wrong way. To guard against such a mishap there is the peculiar provision which enables us to swallow. Now swallowing may not inaptly be compared with what is constantly occurring where two lines of railway intersect, and where the pointsman, therefore, is obliged to block one or other of them whenever a train is about to pass. In the

¹ For an account of "cells" see Chapter XIII.

² See Note at end of Chapter II, and fig. 9, p. 102.

particular case which we are now considering it is the respiratory line which is blocked. For this purpose the nasal passages are closed above by a pushing backwards of the soft palate, and the windpipe is closed below by a pushing upwards of the latter against the base of the tongue, the tongue at the same time being retracted. Thus swallowing involves quite a number of muscles, and not only so, but for a moment or so completely puts a stop to the breathing. This somewhat complicated action may strike us at first as a little unnecessary, for apparently it might so easily have been avoided, if only the two canals, the digestive and the respiratory, had been kept apart. It is a matter, however, to which, as already said, I intend to return later.¹

The food having passed through the mouth and the pharynx enters the gullet, but by the time it has done so it has ceased to be under the control of the will. Its further progress, therefore, along the digestive tube has to be insured by other means. And here another piece of remarkable purposive mechanism comes into play. Embedded in the wall of the tube, and surrounding it along its entire length, is an enormous number of ring-shaped muscular fibres of the involuntary kind, which by their contraction at any point narrow the bore of the tube there, at times very nearly obliterating it. Now, if these contractions took place irregularly—*i.e.* simply anyhow—no useful end would be subserved, but, inasmuch as they follow one another in close and orderly succession along the tube, they force the food in it continually onwards, and always in the required direction.² This peculiar action of the involuntary muscular fibres is what is known as *Peristalsis*.

After the gullet comes the stomach, which is simply a very much dilated portion of the tube, in which the temporarily suspended work of digestion is resumed. But it is no longer now the starchy ingredients of the food which are singled out for attack, but the meaty, the nitrogenous ingredients, the so-called *Proteids*. In order to bring them into a state of solution, another juice differing altogether

¹ See pp. 102, 103.

² In vomiting, of course, the action is reversed.

from saliva is poured out upon them, viz. the gastric juice, which is very acid and is secreted by a large number of minute glands situated in the stomach walls. But as this process takes time, and it would not do, till it is finished, for the food to be allowed to pass on into the intestine, the *Pylorus* or farther end of the stomach is firmly closed by what is known as a *Sphincter Muscle*. Meanwhile, to assist in the digestion, the food is incessantly churned about inside the stomach, and, being thoroughly mixed in this way with the gastric juice, becomes extremely acid.

As the process nears completion the sphincter muscle shows signs of relaxation, and a portion of the food, or of the *chyme*, as it is sometimes called, begins to make its way into the small intestine, where it is almost immediately subjected to the combined action of the bile and of the pancreatic juice. The bile is secreted by what is by far the largest gland in the body, viz. the liver, and one of its principal functions appears to be to break up the fatty portions of the food into a number of infinitesimally small globules, which are thus brought into a fit condition to be absorbed. And here we have to note the relation which exists between the different digestive juices and the different substances which we take in in the form of food. These latter include—if we leave out the water and the soluble salts which do not, of course, require any digestion—first, the *Carbohydrates* or starchy substances; secondly, the *Proteids* or meaty substances; and thirdly, the *Fats*.

Now the remarkable fact in connection with these three chief ingredients of our food is that, although they are all obtained from the world *outside*, there should be formed *inside* the body a special juice corresponding to each of them, and capable of acting on them digestively, viz. the saliva on the starches, the gastric juice on the proteids, and the bile on the fats. It is also a remarkable fact that for the manufacture of these juices special glands should in each case be provided, and that, as already said, each should draw from the same source, viz. the blood, just the materials which it requires.

Another interesting point to be noted is the way in which

each gland is stimulated into activity and always at the right juncture. The secretion of the gastric juice, for instance, is not always going on, neither does it wait to begin till the food actually reaches the stomach. To cause it to flow it is enough for the food to have entered the mouth ; and sometimes, when we are particularly hungry, the mere sight of eatables will produce the same effect, just as the mere sight of them a short time before stimulated the salivary glands and made the mouth water. Now in these cases it is obvious that some sort of nervous signalling must take place. A message, in fact, is dispatched to the brain by means of the optic nerves to the effect that food may shortly be expected, and in response to this, by means of certain other nerves, a second message is dispatched to the glands in the stomach, bidding them get ready for the approaching meal.

In the secretion of the pancreatic juice another kind of signalling is employed. As the pancreas lies close to the stomach, touching it in fact, it might naturally be supposed that the entrance of food into the stomach would at once rouse it into activity. But seemingly this only happens to a slight extent, nor is the reason for the delay far to seek. As food does not simply pass through the stomach, but has generally to remain in it for some hours in order that the gastric juice may complete its work, it is plain that if the mere entrance of food into the stomach caused anything like a full flow of pancreatic juice, the latter would discharge itself into the intestine to little or no purpose. Accordingly what happens is as follows. Digestion in the stomach having proceeded sufficiently far for a portion, at least, of its contents to be admitted into the intestine, no sooner does this portion come in contact with the cells forming part of the intestinal lining than it causes them to produce a peculiar substance known as *Secretin*. This secretin is at once absorbed by the neighbouring capillaries, and, being whirled away in the general blood-stream, rapidly reaches the pancreas, which it at once excites into activity. The result is a very copious flow of the pancreatic juice, which is poured into the intestine almost immediately after the

partially digested portion of food has entered it—that is, just when it is most needed. It should further be noted that it is the acidity of the partially digested food which, by its action on the walls of the intestine, leads to the formation of the secretin. Now the pancreatic juice itself has an alkaline reaction. Hence when a quantity of it has entered the intestine sufficient to neutralise the acidity there, it stops for a time the formation of any more secretin, and thereby stops for a time its own formation. Presently, however, when a fresh portion of the acid contents of the stomach is passed on into the intestine, the action above described is again automatically set up.¹ Now the two points deserving of special notice here are: First, that the message to the pancreas causing it to secrete should be conveyed to it by the circulatory instead of by the nervous system; and secondly, that to all appearances we are presented here with a most extraordinary device for insuring that the secretion shall take place, not too soon, but just when the right moment for it has arrived.

With the bile, which is secreted by the liver, the arrangement is again somewhat different. Bile is not only a digestive fluid; it contains substances which the body wishes to get rid of, to excrete.² Consequently its withdrawal from the blood is a process which is always more or less going on. It is not always, however, being discharged through the bile duct into the intestine at the same rate, for in that case much of it, from the digestive point of view, would be wasted. Hence the need for some special receptacle for storing it up between the successive arrivals of food in the intestine, following upon successive meals. This receptacle is provided by the gall-bladder, in the hollow interior of which a considerable quantity of bile gradually collects, till at the proper time it receives the signal for its discharge. This signal apparently reaches it *via* the nervous system, but the simultaneously increased production of bile in the liver itself is due once more to

¹ Starling's *Principles of Human Physiology*, pp. 709, 710; Halliburton's *Handbook of Physiology*, p. 521.

² As, for instance, those substances which are the result of the disintegration of effete red-blood corpuscles.

the action of the secretin.¹ The only other organ in the body which may at all be compared with the gall-bladder, as regards its retentive function, is of course the urinary bladder, which, greatly to our convenience, need only be emptied at certain intervals, though the urine itself is continually being excreted from the blood by the kidneys. But it is difficult, on the natural selection hypothesis, to understand how such an organ as this last arose, in which mere convenience was the sole end in view.

But to proceed, the food having been digested, brought, that is, as far as possible into the liquid state, and having undergone several other changes of a chemical kind as well, is at last ready to be absorbed into the blood. This is effected by the greater portion of it passing through the internal coat of the intestine into the neighbouring capillaries, and thus into the general circulation at once. The other portion, as will be explained immediately, reaches its destination by a rather more circuitous route. To increase the extent of the absorptive surface the intestine has been drawn out to a very great length, measuring in man no less than thirty feet. This has thrown it into a number of sausage-like convolutions, which are suspended and held in place by the *Mesentery*, which is a kind of membranous bag firmly attached behind to the vertebral column. Further, the internal surface of the intestine is covered all over with a large number of minute finger-like structures of a roughly conical shape, known as *Villi*, and it is these which really do the work of absorption. Each villus projects about one-twelfth of an inch into the intestine and contains a network of very fine capillaries, through which the blood is continually circulating and into which the principal products of digestion find their way. The tiny globules, however, into which the fatty portions of the food have been broken up, are for the most part absorbed by the little tubes known as *Lacteals*, one of which runs down the centre of each villus. From these lacteals they are slowly passed along through a succession of somewhat complicated other tubes, the so-called *Lymph Vessels*, till they reach at last the *Thoracic*

¹ Starling's *Principles of Physiology*, pp. 713-716.

Duct, which at its anterior, and in man its upper, end delivers its contents into one of the great veins near the heart. Thus, though by two entirely distinct routes, all the digested materials are finally taken up by, and incorporated in, the blood.

SUMMARY

The following are the various arrangements to which I have drawn attention in this chapter as being specially exhibitiv of purpose :—

1. The existence in the first instance of a digestive sac or cavity, as without some such cavity digestion could only be carried on to a very limited extent.

2. The transformation of this, in all animals above the Coelenterates, into a tube open at both ends, through which the food is gradually propelled onwards.

3. A muscular mechanism, for the most part independent of the will, for thus propelling it.

4. Special mechanisms near the mouth end of the tube for masticating the food and subsequently swallowing it.

5. The existence of a number of glands for secreting the various digestive juices which

- (a) differ from one another according to the particular ingredients in the food, which they have severally to digest ;

- (b) and yet are all extracted from the same fluid, namely, the blood.

6. At least two different methods, by which the secretion of these juices is timed, one of them being connected with the nervous and the other with the circulatory system.

7. The extraordinary automatically working arrangement by which the flow of the pancreatic juice is regulated.

8. The existence of a gall-bladder for retaining a certain quantity of bile till it is wanted for digestive purposes.

9. The closure and subsequent reopening of the orifice at the farther end of the stomach, according to the stage at which digestion in it has arrived.

10. The drawing out of the intestine (in man) to a length

of thirty feet, so as to secure a sufficient extent of absorptive surface.

11. The provision of a mesentery for keeping the intestine thus drawn out in its proper position.

12. The villi with their peculiar structure, by means of which the various products of digestion are at last received into the blood.

To the above I may add, that whatever may be the special purpose fulfilled by any individual organ belonging to the digestive system, such organ is only of real use in so far as, working in conjunction with the rest, it contributes to the larger purpose for which they all exist, namely, that of converting the various needful food substances from the solid into the liquid state, and of thus making it possible for them to be absorbed into the general system. Obviously it is this larger purpose which alone matters, and to which all the lesser purposes are merely subsidiary and lead up.

Note.—The following books amongst many others may be consulted for further information on the subject treated of in this and the next five chapters :—

Physiology.—Huxley's *Elementary Lessons in Physiology*, Thornton's *Advanced Physiology*, and such larger works as Halliburton's *Handbook of Physiology* and Starling's *Principles of Physiology*. Also an excellent article on "The Body-Machine and its Work" in *The Outline of Science*, by J. Arthur Thomson, pp. 239-272.

Anatomy.—Gray's *Anatomy, Descriptive and Applied*, Sobotta's *Atlas and Textbook of Human Anatomy*.

Zoology.—J. Arthur Thomson's *Outlines of Zoology*, Bourne's *Comparative Anatomy of Animals*, Parker and Haswell's *Textbook of Zoology*, 2 vols.

CHAPTER VII

THE RESPIRATORY SYSTEM

For the maintenance of life it is not enough that an animal should be supplied with food and that the latter should be brought into a liquid and, therefore, into an absorbable condition by means of digestion. For though the energy which an animal requires for the performance of its numerous activities is already present in the digested materials, it is only there in potential form, and cannot be of any service to the organism till it has been converted into kinetic energy—the energy of heat and of muscular movements, etc. But this, as was explained in Chapter III, can only be done by means of oxygen, which, with its singular avidity for the carbon compounds contained in the digested materials, breaks up their complex molecules, and so renders the energy in them available. Respiration, therefore, or the taking in of oxygen, is quite as essential to life as the taking in of food. Neither apart from the other would be of any use.

Seeing, however, that a large amount of oxygen happens to be present in nearly all the principal food-stuffs—forming about 11 per cent. by weight in the fats and about 50 per cent. by weight in the carbohydrates—the question might naturally be asked, Why should it be necessary to take in any additional amount of it from the air? The reason is that the oxygen contained in the said food-stuffs is quite useless for the purpose required, inasmuch as it exists in them in fast chemical combination with other elements, and with these it could not be induced to part, except by a considerable *expenditure* of energy. What is really wanted, then, is free *uncombined* oxygen, and of this there is always a practically unlimited supply in the surrounding atmosphere,

which, it will be remembered, is not a compound of oxygen and nitrogen, but simply a mixture of the two. Water, on the other hand, as explained in Chapter III, is not a mixture but a compound of oxygen and hydrogen, and, therefore, once again the oxygen in it is quite useless for respiratory purposes. As to fishes and other organisms living in water, they are compelled to breathe just like animals living on land, but they get their oxygen not out of the water but out of the air, which is always to a greater or less extent dissolved in it. Put fishes into water which has been previously deprived of air by boiling, and they will be suffocated.

But although food and oxygen are equally necessary for life, there is in their relation to life one important difference between them, in so far at least as animals are concerned. For animals, as we have seen (Chapter IV), are compelled to go in search of their food on account of its comparative scarcity, and, because of this, have been provided with special organs of locomotion. But with the oxygen they require the case is wholly different. There is no need for them to go in search of it, or to put themselves to any kind of exertion in the matter; because, as above stated, there is always so unlimited a supply of it present in the atmosphere.

But this at once suggests the interesting question: To what extent would animal life during the past geological ages have pursued its distinctive line of advance if food had been as readily obtainable as air? It is not likely that it would have pursued it very far, for it is precisely the imperative need for food which has been in animals the chief incentive to their activity. And this, coupled with the ever-changing relations into which they have been brought with the environment as the result of their enforced locomotory movements, has undoubtedly had much to do with the gradual evolution in them of the nervous system, and of those wonderful powers of instinct and intelligence which have become so mysteriously associated with it.

Again, we can scarcely fail to note the important bearing

of what has just been said upon Man himself. For at that distant epoch, when he first made his appearance upon the earth, what would there have been to rouse him into activity and to set him on his path of apparently endless progress, if he had been exempted from the law to which all the lower forms of animal life had been obliged to submit, and he had found it as easy a matter to obtain the necessary food as to obtain the necessary oxygen? Even to-day it is the same stern law under which we are all compelled to live. Whatever may be the hidden underlying purpose of it—granting that such exists—the human race has still to labour, and to labour unceasingly, for its daily bread.

But if now, so far as oxygen is concerned, we are not compelled to go in search of it, and if, moreover, oxygen, being a gas, does not require to pass through any preliminary process similar to digestion before it can be absorbed, there are still certain special problems in connection with the respiration of it which Life had to solve.

The first problem is related to the fact, that for the complete combustion of a given quantity of food an exceedingly large volume of air is needed. For instance, in order to consume a single pound of stearine ($C_{57}H_{110}O_6$), which is one of the chief constituents of fat, and to get out of it, therefore, all the energy it contains, no less than 150 cubic feet of air are required. But the volume of air which our system demands, and which has daily to pass through our lungs, is considerably in excess of this, ranging from 231 to 393 cubic feet, an amount which may be more than doubled if we engage in exercise of at all a strenuous kind.¹ The problem, therefore, to be solved was this: How exactly was so enormous a volume of air—enormous as compared with the size of the human body—to be got hold of? Plainly it could not be taken into the system like food, only three or four times a day, for there would not be room enough in the body for the storage of sufficient quantities of it between successive meals. The difficulty, then, could only be met by its being taken in in only very small

¹ Halliburton, *Handbook of Physiology*, p. 359.

quantities at a time, but with extreme frequency, viz. in Man on an average of about sixteen times a minute, which means considerably over 20,000 times a day. Hence, for the preservation of life, the respiratory function has constantly to be maintained, and maintained not only during the daytime, when all our faculties are awake, but during the unconscious hours of sleep. This is necessitated by the fact that among other things the movements of the heart and of the blood along the arteries and veins must never be allowed to stop, which movements involve a continual expenditure of energy and, therefore, a continually renewed supply of oxygen. Hence, to avoid any risk of the respiratory function being brought to a standstill during the night, it had to be rendered independent of the will by putting it under the control of a special nervous centre situated in the lower part of the brain, viz. the *Medulla oblongata*—that part which never goes to sleep, and which stands in no direct relation to our consciousness.

But there was another problem in connection with the respiratory function which Life had to solve. We saw in the last chapter that to provide sufficient surface for the absorption of the products of digestion, the intestine had to be drawn out to a somewhat inordinate length, and to be thrown, in consequence, into a large number of convolutions. But the extent of surface required for the absorption of the necessary amount of oxygen is immensely greater than that afforded by the internal coat of the intestine, being equal, in the case of Man, to about 120 square yards.¹ Why it should be as great as that we need not perhaps stop to inquire, but the interesting point is that our lungs have been so constructed, that the problem in question has been solved and in the following manner. The windpipe, as it descends into the cavity of the chest, divides into two branches, the *Bronchi*, one for each lung. Each of these on entering the lung divides again, and continues to divide, much after the same fashion as the trunk of a tree, till, answering to the ultimate twigs of the latter, certain final subdivisions are reached. These all end blindly in an

¹ Halliburton, *Handbook of Physiology*, p. 353.

enormous number of minute cuplike cavities, or air-sacs, varying from $\frac{1}{50}$ th to $\frac{1}{70}$ th of an inch in diameter. Seeing that there are several millions of them in each lung, it is simply a matter of arithmetic to show that the sum total of their internal surfaces mounts up to about the 120 square yards required. Further, to absorb the oxygen, round each of these minute air-sacs, the walls of which are almost as thin as soap-bubbles,¹ there is a network of extremely fine capillaries, through which the blood is continually circulating.

Now it is very instructive to compare this state of things with what we find to be the rule among plants. Plants breathe as well as animals, though much more slowly, taking in from the atmosphere both oxygen and carbon dioxide. In order to do this they need, like animals, a large absorptive surface. Instead, however, of developing *internally* a branch-like system of hollow tubes ending in air-sacs, they have gone in for an elaborate system of *external* branching, the ultimate ramifications of which bear leaves, through the outer surfaces of which the oxygen and the carbon dioxide find their way in (see Chapter IV). Now this, in striking contrast to the other, would seem to be a considerably simpler arrangement, and in fact it is the one which has frequently been adopted by those animals which live in water and breathe by means of gills. With the higher animals, however, living on land—from the amphibians in their adult state up to Man—lungs have been developed, the construction of which is on exactly the opposite plan. Nor is it difficult to assign the reason for this. In birds, and mammals more especially, with their much higher temperatures and greatly increased activities as compared with lower animals, there was need for a proportionately increased extent of absorptive surface. But to have secured this by the same method as in plants would probably have meant—to take our own case alone—the addition to our present bodies of one or more very cumbrous, very much branched external appendages, which not only would most seriously have impeded us in all our various movements

¹ J. A. Thompson, *The Outline of Science*, p. 254.

and have been extremely inconvenient, but would have proved an unceasing menace to life. For as the blood circulating through the capillaries would have had to flow very near the surface for the work of absorption to be carried on, there would have been constant danger of hæmorrhage, not to speak of the other accidents which might so easily have occurred through rough contact of such delicate structures with surrounding objects.

Thus we see the inner reason, so to speak, which among the higher animals led to the development of lungs, inasmuch as by their peculiarly constructed internal system of hollow tubes and air-sacs, they afford protection for their extremely thin absorbing surfaces against external injuries.

At the same time this arrangement was not without a certain drawback—a drawback which had somehow to be overcome. A plant, a forest tree for example, needs no special machinery for the renewal of the air which bathes it on all sides. Every breath of wind brings fresh oxygen and carbon dioxide to its outspread foliage, and even when the atmosphere is apparently quite still, there is no cessation of its movements, for its molecules are never for an instant really at rest. But with an internal system of branching air passages it is obvious that some kind of special contrivance had to be employed for effecting a continual exchange of the air inside them with the air of the surrounding atmosphere. Otherwise the oxygen in the lungs would very soon have become exhausted.

Now the contrivance actually employed is as follows. First, the lungs are placed in a kind of box, namely, the general cavity of the chest, to the inside walls of which their outside surfaces are kept closely and constantly applied by means of the atmospheric pressure existing in the air-sacs. The size of this cavity, however, is incessantly undergoing change, being alternately increased and diminished, much after the same manner as the space inside a pair of bellows. This is effected in part by the *Diaphragm*, a large muscular organ, which in mammals forms the floor of the box, and serves completely to shut off the abdomen, or

lower part of the body. In its uncontracted state the diaphragm, as viewed from above, is convex, but at each contraction, which occurs whenever a breath is drawn in, it flattens itself out, and by so doing enlarges the cavity of the box. Again, attached to the ribs, forming the sides of the box, there are two distinct sets of muscles which also assist. When the outer set contract, the ribs are elevated in front and the cavity is increased, but when the inner set contract, the ribs are depressed and the cavity is diminished. By the working, then, of this somewhat complicated piece of mechanism, the air is alternately sucked down into the lungs and afterwards expelled, the entire action being repeated, as already said, some sixteen times a minute. In this way the required solution of the problem has been accomplished.

There are, moreover, two other little niceties in connection with the subject which deserve mention. And, first, in order that when the cavity of the chest expands, the lungs may expand with it—for the expansion of the chest would in itself accomplish nothing—the lungs are composed of a peculiarly elastic material, which, whenever an inspiration occurs, causes them to swell out and completely fill the cavity. Also, they are aided in this by the atmospheric pressure already alluded to as existing in the air-sacs. Secondly, although the outer surface of each lung is closely applied to the inner surface of the chest, any kind of adhesion between them is carefully prevented by a lubricating fluid, which, like all other secretions in the body, is furnished by the blood, and which, by permitting a certain amount of sliding movement, considerably facilitates the breathing process.

SUMMARY

1. Oxygen is as necessary to life as food. Only by its means can the energy contained in food be unlocked.
2. It must be free uncombined oxygen.
3. As there is practically an unlimited supply of it in the atmosphere, no animal need go in search of it.
4. Being a gas, it does not require to pass through any

preliminary process corresponding to digestion before it can be absorbed.

5. But being a gas and, therefore, extremely light, there is not room enough in the body for the amount required, except by taking it in in very small quantities at a time.

6. Hence the respiratory act has incessantly to be repeated—in Man some 20,000 times per diem.

7. As the process must not be allowed to stop by day or by night, it has been rendered independent of the will by being put under the control of a special nervous centre in the lower part of the brain.

8. For the absorption of the necessary amount of oxygen an absorptive surface of very large extent is required, measuring in ourselves no less than 120 square yards.

9. This surface is situated in the lungs, and is provided by the millions of air-sacs in which the very fine ultimate branches of the windpipe terminate.

10. For all the higher animals at least such a system is greatly preferable to that system of external branching which has been generally adopted by plants. The latter in ourselves, for instance, would not only cause great inconvenience, but seriously imperil life.

11. Such a system, however, of internal branching has led to a certain complication. It has necessitated a special mechanism, in which several muscles play their part, and by means of which the air inside the lungs is continually being exchanged with the air of the atmosphere outside.

12. As assisting in this we have, moreover—

- (a) The peculiarly elastic character of the lungs themselves ;
- (b) the atmospheric pressure inside the air-sacs ;
and
- (c) the lubricating fluid which bathes the outer surfaces of the lungs.

Finally, I would observe that in the various arrangements above described, the appearance is as though Life had been trying to solve a certain definite problem, viz. how to lay

hold of an amount of oxygen sufficient for all the requirements of the organism, and in doing so to pay due regard to all the special conditions of the case, such as the size of the human body, the gaseous nature of oxygen and its consequent extreme lightness, the need of a very large surface through which the absorption can take place, and the further need that this surface should not be exposed in such a manner as to endanger life.

CHAPTER VIII

THE CIRCULATORY SYSTEM

THE processes hitherto described by which food and free oxygen are obtained and rendered serviceable to animal life would very inadequately fulfil their purpose, unless some provision had been made for the conveyance of these substances to all the different parts of the body, and especially to those concerned with movement and secretion. Now such a provision we find in the circulatory system which, although it may be said to exist in a rudimentary form among even the lowest animals like the Protozoa and the Cœlenterates, has in the course of evolution been carried to a very great degree of perfection in the highest animals of all. It may not inaptly be compared, indeed, with the means employed in a country like our own for the transport to inland places of the food and of the various raw materials brought to our shores. And just as with the progress of civilisation good roads have gradually superseded bad ones, and in more recent times railways have spread their network over the length and breadth of the land, thereby speeding up every kind of industry, so has it been in a manner with the circulatory system among the higher animal groups. It has undergone during the vast geological periods a most remarkable series of changes rendering it continually more and more efficient ; and these, combined with a series of parallel changes in the respiratory organs, have enabled the Mammals and the Birds, which stand at the head of the animal kingdom, not only to maintain temperatures considerably higher than that of their surroundings, but to exhibit an amount of activity far in excess of that of the majority of the lower forms of life.

Confining attention, however, to the circulatory system

as it is found in ourselves, we have briefly to consider (1) the circulating fluid or blood, (2) the vessels through which it circulates, (3) the circulation itself, and (4) the means by which the circulation is maintained.

The blood, which forms about $\frac{1}{10}$ th of the total weight of the body, consists of a yellowish liquid, the *Plasma*, in which are suspended an immense number of minute particles, the so-called *Blood Corpuscles*. Of these there are some 80,000 millions in every cubic inch of blood, the total number of them in the whole body mounting up to about 25 trillions. The great majority of them are of the red variety, and give to the blood its well-known characteristic tint. They are disc-like in shape, resembling coins, but with sides slightly concave. They measure about $\frac{1}{2500}$ th of an inch in diameter, and being flexible, like pieces of india-rubber, can squeeze themselves when required through narrow openings. Further, they are impregnated with a substance known as *Hæmoglobin*,¹ which imparts to them their peculiar colour, and which, as we shall see presently, has a most important function to fulfil. Their span of life is brief, lasting only a few weeks, but their numbers are continually being replenished in the *Red Marrow* found inside the larger bones. When effete they are finally destroyed in the liver and the spleen.

As to the white corpuscles, they are far fewer in number, viz. one to about every five hundred of the red ones. They differ from them not only in tint, but in the remarkable way in which they keep changing their shapes, putting out little processes here and there, and afterwards retracting them like the *Amœba* among the Protozoa.² One of their principal duties appears to be to encircle and devour unbidden guests, such as the bacteria of disease, should they happen to gain entrance into the body. Also they remove dead tissues and such as are no longer of any use. Thus the gradual shrivelling up of a tadpole's tail, when the tadpole is being transformed into a frog, is largely due to their activity.

¹ Its chemical formula is stated to be $C_{758}H_{1203}N_{195}O_{218}S_2Fe$. Each molecule of it contains, therefore, 2378 atoms.

² For a description of an *Amœba* see Chapter XII, p. 139.

The vessels through which the blood circulates consist of the heart, the arteries, the capillaries, and the veins. The heart, which is a muscular organ about the size of a man's

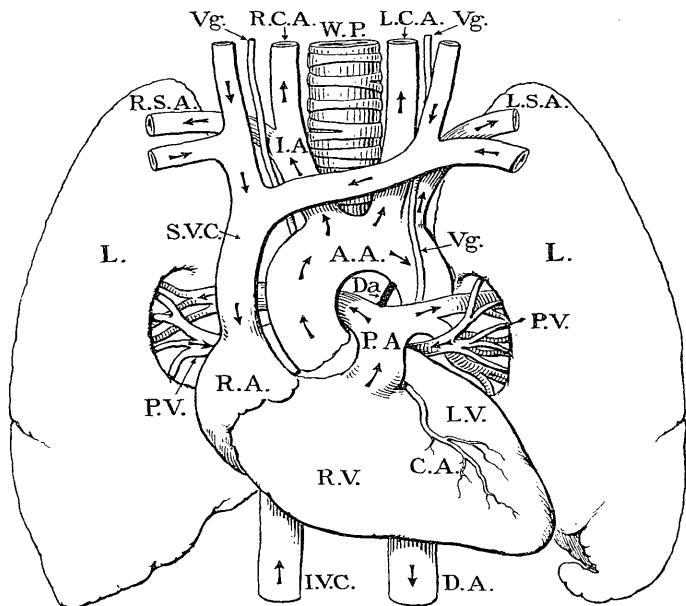


FIG. 6.—HEART, LUNGS AND PRINCIPAL BLOOD VESSELS.

R.A., Right auricle; R.V., Right ventricle; L.V., Left ventricle (left auricle concealed); L.L., Lungs; W.P., Windpipe; A.A., Aortic arch; D.A., Descending Aorta; C.A., Coronary artery; I.A., Innominate artery; R.C.A. and L.C.A., Right and left Carotid arteries; R.S.A. and L.S.A., Right and left Subclavian arteries; P.A., Pulmonary artery; D.A., Ductus arteriosus (blocked); S.V.C. and I.V.C., Superior and inferior Venæ Cavæ; P.V., Pulmonary veins; Vg., Vagus nerves supplying heart, etc.

fist, contains four chambers, of which the two upper ones are known as the *Auricles* and the two lower ones as the *Ventricles*. The right auricle communicates through an opening with the right ventricle immediately beneath it, and similarly the left auricle communicates with the left

ventricle ; but there is no direct passage between the two sides of the heart.¹ It somewhat resembles, therefore, in this respect a pair of semi-detached villas each with a room above and a room below. The blood in its outward journey to the different parts of the body, the lungs excepted, starts from the left ventricle and passes at once into the *Aorta*, which is the main artery and from which by continually repeated branchings all the other arteries arise. At first the aorta proceeds in the direction of the head, but it soon bends downwards, backwards, and to the left, forming a kind of arch, till by piercing the diaphragm it enters the cavity of the abdomen. Here it gives off several side branches to the stomach, intestines, liver, pancreas, spleen, kidneys, etc., after which it forks, dividing into two portions, which prolonged downwards supply the lower limbs with blood. Near the heart and just at the bend of the arch the aorta gives off three branches, the first of which, the *Innominate Artery*, soon divides into the right *Subclavian* and the right *Carotid*. The other two branches are the left carotid and the left subclavian. The carotids supply the head with blood, while the subclavians chiefly supply the arms.

As the arteries continue to subdivide, their branches become smaller and smaller, till at last they merge imperceptibly into the capillaries. These last form a network of very fine interlacing tubes which penetrate into every part of the body except the cartilages and a few other structures, as for instance the hairs and the nails. They even make their way into the hardest bones.

Unlike, however, the ultimate branchings of the air-tubes in the lungs and of the ducts in the various glands, all of which end blindly, the capillaries soon begin to unite into larger tubes or veinlets, and these again into still larger ones or veins, and so on until at last they have all united into two great trunks, the superior and the inferior *Venæ Cavae*, which open and discharge their contents into the right auricle of the heart. Thus the blood having travelled outwards through the arteries and worked its way through the

¹ Though, as we shall see in Chapter XVI, there is such a passage in the unborn child, p. 209.

capillaries, returns to the heart by the veins, and by so doing completes what is known as the *Systemic Circulation*.

But it has still another journey to accomplish, namely, the journey to and from the lungs. With this in view it passes direct from the right auricle into the right ventricle, and thence into the *Pulmonary Artery*, which on leaving the heart divides almost immediately into two branches, one for each lung. On entering the lungs these break up still further, and after repeated subdivisions end in the minute capillaries which, as stated in the last chapter, closely invest the innumerable cuplike air-sacs forming the ultimate ramifications of the windpipe. Next, the capillaries unite into small veins, and these into larger ones, until finally by four principal veins, two from each lung, the blood returns to the left auricle of the heart, thereby completing what is known as the *Pulmonary Circulation*. Passing now direct from the left auricle into the left ventricle, it comes back to the place from which it originally started, and is thus ready to go through precisely the same cycle as before. It has been roughly estimated that the entire circulation—the systemic and the pulmonary circulations taken together—occupies on an average rather less than a minute.¹ I may add that the aorta gives off close to its origin two small arteries, the *Coronaries*, which supply the heart itself with blood—that is to say, its muscular walls—and supply it, therefore, with the energy which it needs for doing its work. Were this supply cut off death would immediately ensue.

Now without dwelling for the present on the extraordinary elaborateness of all these arrangements, and of the others yet to be described, we have next to consider the different purposes which they subserve. In the first place, the blood in its passage through the capillaries of the intestine absorbs the products of digestion, and afterwards conveys them to the various organs and tissues of the body, especially to the muscles and the glands, as well as to all growing parts and to such as may be in need of repair. Again, in its passage through the capillaries of the lungs

¹ Halliburton, *Handbook of Physiology*, p. 290.

it absorbs the oxygen and deals with it in a manner closely similar, but with this difference, that, whereas the products of digestion are conveyed to their destination by the plasma of the blood, the oxygen is conveyed by the red-blood corpuscles, this apparently being their specially assigned task. The oxygen, it seems, enters into some sort of loose chemical combination with the hæmoglobin, with which, as we have seen, the red corpuscles are impregnated, and forms with it a substance known as *Oxy-hæmoglobin*. When, however, in the course of the circulation the red corpuscles reach the tissues, they deliver up this oxygen, which is able now to attack the carbon compounds derived from the food and, by breaking up their complex molecules, to transform the potential energy contained in them into the different forms of kinetic energy required. Thus at the end of these many highly elaborate processes the great purpose is at last achieved for which the digestive, the respiratory and the circulatory systems are alike necessary, viz. that of enabling the body to perform all its manifold activities by means of the power originally extracted from the sun's rays by the agency of plants.

I may observe here that the rapidity of the circulation among the higher animals, and the intricacy and the perfection of the organs concerned in it, have much to do with the rapidity, the intricacy, and the perfection of their varied movements. It would seem almost as though Evolution had been deliberately striving after this end from the first, so that again I would point out the analogy which it thus presents to the way in which the industrial productiveness of a country is increased by almost every fresh improvement made in its means of inland communication.

Another interesting point which may be mentioned, is that among the Invertebrates methods of quite another kind are sometimes employed for conveying the oxygen to the tissues. Thus insects possess neither lungs nor gills, nor any other organs in the least answering to them; but they take in air through a number of small apertures—the *Stigmata*—which are arranged in two rows, one down each side of the body. These conduct into an extremely com-

plicated set of air-tubes, the ramifications of which extend everywhere—even into the nervature of the wings, as in the case of moths and butterflies. By this means the oxygen is carried direct to every organ without the intervention of the blood as the carrying agent. Such a method, however, would probably have been quite impracticable in animals attaining the size of the majority of the Chordates, as for example ourselves.

The blood on its return to the right auricle by the superior and inferior venæ cavæ has not only parted with its oxygen and assumed in consequence a purplish tint, but it has become charged with a number of waste products. These it has next to get rid of, which it does chiefly by means of the lungs, the skin, and the kidneys. Hence the lung are not only organs by which oxygen is absorbed, but organs by which certain effete substances are excreted—more especially the carbon dioxide which has resulted from the combustion in the tissues of the various carbon compounds. By eliminating this poisonous gas and at the same time providing itself with a fresh supply of oxygen, the blood is restored in the lungs to its previous bright red colour.

We have now to consider the special mechanism by which the circulation of the blood is maintained. As already said, the heart is a muscular organ—that is, its walls are almost entirely composed of muscular fibres. These are arranged in such a manner that whenever they contract, the internal cavities—the auricles and the ventricles—become practically obliterated, and the blood in them is consequently driven out into the surrounding vessels. It must be obvious, however, that this in itself would not be sufficient to cause the blood to circulate in the manner above described. Means must be taken to make it flow always in the same direction, namely, from the heart through the arteries into the capillaries, and from the capillaries through the veins back to the heart.

To secure this end we have first to note that the muscular fibres of the heart contract not all at once, but in a certain definite order. The auricular fibres contract first, forcing the blood contained in the auricles into the ventricles. This

lasts about the tenth of a second. Next, during three-tenths of a second the ventricular fibres contract, forcing the blood into the arteries. After that for four-tenths of a second the contractions cease, at the end of which period the same set of movements begins over again. Thus on an average the heart beats, as we say, some seventy-five times a minute, though its actual frequency depends on several causes, such as the age of the individual in question and the amount of exercise which he may be taking at the time. Immediately after birth the frequency may mount up as high as one hundred and forty, while in old age it may sink as low as sixty. Another remarkable thing about these movements is that, although they are to a certain extent under the control of nervous influences emanating from the lower part of the brain, as also from what is known as the *Sympathetic System*, they are nevertheless in a manner independent of them. In other words, the rhythmical contractions of the heart appear to be primarily due to some cause inherent in the heart itself, as is shown by the fact that in the embryo the heart begins to beat previous to any connection being established between it and the nervous system. It has also been shown¹ that muscle cells can be removed from the heart of a chick and artificially kept alive in an appropriate liquid concoction for several years, and that during this period they will keep on rhythmically contracting.

But, secondly, the mere fact that the heart contracts rhythmically would not bring about the desired effect, apart from that extraordinary arrangement of valves by which the flow of the blood is directed. Of these valves the most important perhaps are those which guard the opening on each side of the heart between the auricle and the ventricle, allowing the blood to pass freely from the former into the latter, but not in the opposite direction. The *Mitral Valve*, which is situated on the left side of the heart and which is so called from its fancied resemblance to a bishop's mitre turned upside down, is a membranous structure attached

¹ See the Harveian Oration on "The Wisdom of the Body," by Professor E. H. Starling, October 18, 1923.

to the rim of the orifice between the auricle and the ventricle. Hanging down into the latter it terminates below in two flaps which, so long as they remain in that position, leave open the passage between the two chambers—a state of

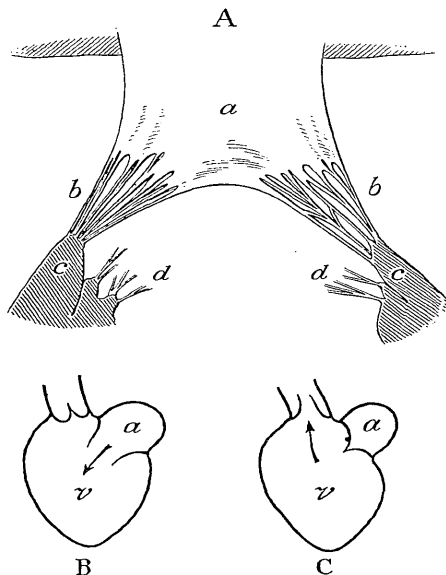


FIG. 7.—A. Mitral Valve. *a*, One of the flaps; *b*, Tendinous cords; *c*, Conical projections; *d*, Cut ends of cords attached to the other flap. B. One side of Heart during auricular contraction. C. One side of Heart during ventricular contraction. *a*, auricle; *v*, ventricle.

things which continues during the auricular contraction. No sooner, however, does the ventricle contract, than the pressure of the blood inside it drives the flaps upwards and causes them to meet along their edges, thereby closing the orifice and so preventing any return of the blood into the auricle. Further, that these flaps may not be driven up too far, so as to protrude into the auricle and thereby reopen the orifice, they have attached to their edges a number of tendinous cords which are fastened by their lower ends to certain little

conical projections arising from the inner wall of the ventricle. Accordingly, when the ventricle contracts, these cords are drawn tight and hold the flaps in just the right position. But there is a still further nicety. As during the contraction of the ventricle its walls are necessarily brought nearer and nearer together, there would naturally be a tendency towards the end of the contraction for the cords in question to

become slack and so cause the flaps to separate again. This is prevented, however, by the action of the little conical projections just mentioned, which are of a muscular nature and which always at the right moment shorten themselves in such a way as to keep the cords constantly on the stretch—surely a most marvellous provision, however its origin may be accounted for. Almost as marvellous is the fact that, although these flaps are incessantly working to and fro at the rate of seventy-five times a minute, with the cords attached to them now slackening and now being pulled tight, they seem well-nigh incapable of wearing out. Thus in a man sixty years of age they must have swung backwards and forwards more than two thousand million times.

With regard to the blood-vessels there are two interesting adaptations to which brief reference may be made. In the first place, it is obvious that for the heart at each of its contractions to inject blood into arteries which are already full, the walls of the latter must be more or less elastic. If they were rigid and unyielding, like tubes made of metal, the heart would be quite unable to do its work. Accordingly they are composed in part of elastic fibres.

Again, seeing that the activity of the different organs in the body, and especially of the muscles and of the secreting glands, varies greatly from time to time, it is necessary that the amount of blood supplied to them should vary correspondingly. To effect this, the middle coat of the arteries is formed chiefly of muscular fibres circularly arranged, much in the same manner as those which surround the food canal and are the cause, as we have seen, of its peristaltic movements. According, then, to the degree of the contraction of these fibres will the internal bore of the arteries be either enlarged or diminished, and the supply of the blood to the organ or organs in question be promoted or hindered. It would take too long to describe the precise method by which the necessary adjustments are carried out. Enough, however, has been said on this and other matters to make clear the extremely complicated character of the circulatory system, and to show how every minute detail

of it conduces to the one great purpose of rapidly conveying to the various tissues, and in proportion to their needs, the nutriment which has been rendered available for them by the digestive system, and also of conveying to them the free oxygen which has been taken in by the lungs.¹

I have stated more than once that with the progress of Evolution the circulatory system has gradually been rendered more and more efficient, thereby enabling the animal organism to put forth an ever-increasing amount of energy. The changes, however, which have been effected have been of so intricate a kind, that I will not do more than indicate very briefly the more important ones. Starting from the *Amphioxus*, which may be said to represent the lowest stage in the development of the Chordates, its heart, if it can be called a heart, consists of a simple tube running in a straight line along the under side of its body, but with no indication whatever of any division into chambers, such as auricles and ventricles. By its successive contractions it drives the blood forward into the capillaries of the gills,² to be oxygenated there, but the vessels formed by the reunion of these capillaries, instead of returning the blood to the heart at once, as in the case of the pulmonary veins in ourselves, run backwards to distribute it to the various parts of the body by means of a second set of capillaries. These latter gather themselves up into veins, and finally into one large vein, which prolonged forwards is continuous with, and merges into, the tubular heart. It will be seen, therefore, that in the *Amphioxus* there is nothing corresponding to that double system of circulation which is found in the Birds and the Mammals, and that the so-called heart, by having to force the blood through two sets of capillaries in succession, has a very considerable amount of resistance to overcome.

Practically the same arrangement is found in the majority of Fishes, except that the heart has now been bent upon

¹ I have been obliged in the above account to omit all reference to the *Portal Circulation* and to the circulation of the lymph.

² Or rather into those organs which in *Amphioxus* answer to gills.

itself in the form of an ∞ , and, further, has developed two dilatations—a primitive auricle and a primitive ventricle.¹ In the *Dipnoi* or *Lung Fishes*, which are somewhat higher than the ordinary fishes, the primitive auricle has begun to show signs of partition into a right and a left chamber. In the Amphibians, which come next above them in the scale, this partition has become complete, so that in the frog, for example, the heart is definitely three-chambered, having two auricles and one ventricle. In the Reptiles a still further advance has been made, an imperfect partition having arisen in the ventricle, while among the Crocodiles, which are the highest modern representatives of reptilian life, this partition has also become complete, and the heart is now provided with two ventricles as well as with two auricles. Yet even so we do not arrive at a perfect separation between the systemic and the pulmonary circulations. The reason is that in crocodiles the right ventricle—the blood in which has been depleted of its oxygen—gives rise not only to the vessels going to the lungs, but to a right aortic arch, which lower down unites with the left aortic arch to form a single trunk, the branches of which supply with blood all the posterior parts of the body. This blood, therefore, is only imperfectly oxygenated, being the result of the mixture of two streams, one coming from the right and the other from the left ventricle. Hence it is only amongst Birds and Mammals that we get, along with the four-chambered heart, an arrangement which insures that only thoroughly oxygenated blood shall be carried to all the different parts of the body. The essential point to be noted, however, is this, that the development, which we have now briefly traced, would appear to have had for its ultimate object such a perfection in the structure of the heart and of the related system of blood-vessels, as to enable the higher forms of animal life to display the maximum amount of activity.

¹ To simplify the account I have omitted all reference to the sinus venosus and the truncus arteriosus.

SUMMARY

1. Digestion and Respiration are insufficient, in all animals except the lowest, for the proper maintenance of life. Some means has to be provided by which the ingested food and free oxygen can be rapidly conveyed to all parts of the body.

2. This is accomplished by the Circulatory System, which in the course of Evolution has reached an extraordinary degree of efficiency among the higher animals.

3. In Man and in Mammals generally, as also in Birds, this system consists of a four-chambered heart and of an elaborate set of blood-vessels—of arteries, capillaries, and veins. Contained in these is the circulating fluid or blood.

4. The blood is composed of a yellowish liquid, the plasma, and of a vast number of minute particles suspended in it, viz. the red and the white corpuscles.

5. The plasma conveys to the various tissues the complex carbon compounds contained in the food, the red corpuscles convey the oxygen, while the white corpuscles act as the general scavengers of the body.

6. Arrived in the tissues the oxygen attacks and breaks up the said carbon compounds and thus sets free and renders available the energy originally extracted by plants from the sun's rays. To this great and important end the Digestive, the Respiratory, and the Circulatory Systems all contribute and are all alike necessary.

7. To maintain the circulation of the blood there are the following arrangements :—

- (a) The walls of the heart are muscular and are made to contract rhythmically, viz. some seventy-five times per minute.
- (b) Their contraction takes place automatically and is entirely independent of the will.
- (c) Valves of a peculiar construction have been placed inside the heart, at the entrance of the aorta, and at other important points to insure that the blood shall always flow in the right direction.

- (d) The walls of the arteries have been made elastic; as otherwise the heart would be unable to do its work. They also contain muscular fibres which, by their greater or less contraction, and as required, control the amount of blood flowing to the different parts.

8. In passing up from the Amphioxus through the Fishes, the Lung fishes, the Amphibians, the lower Reptiles and the Crocodiles to the Birds and Mammals, a most remarkable progress is to be observed in the gradual evolution of the four-chambered heart, which has led eventually to the complete separation of the pulmonary and systemic circulations.

Additional Note.—There are other purposes which the blood fulfils besides those above described. Thus by its circulation it tends to equalise the temperature of the different parts of the body, by conveying heat from those organs in which combustion is most actively going on, to others in which the process is comparatively slow. In this respect the arrangement resembles somewhat the system of hot-water pipes, by means of which many of our public buildings are warmed. Again, in a manner very imperfectly understood, it helps in the Mammals and the Birds to keep their temperatures practically constant—thus in Man at a temperature of 98.4° F. Directly there is the least tendency to exceed this limit, the muscular walls of the smaller arteries and capillaries supplying the skin become relaxed, causing an increased flow of blood through them, and consequently an increased loss of heat from the general surface of the body. Conversely, when the tendency is for the temperature to fall below 98.4° F., the aforesaid muscular walls contract and so bring about an exactly opposite effect.

Another purpose fulfilled by the circulation of the blood is the conveyance of white corpuscles in greatly augmented numbers to whatever part of the body may be attacked by the microbes of disease, for, as we have already seen, it is one of the chief functions of the white corpuscles to come

to 'our rescue at such times and to do battle with the intruders.

Again, it is by means of the circulation of the blood that not only secretin, but a number of other mysterious substances necessary to life and known to-day as *Hormones*, are whirled away from the *Ductless Glands* in which they are formed and carried to their proper destinations elsewhere in the body. Of these ductless glands the principal ones are the *Thyroid* and the *Parathyroids* in the region of the throat, the *Pituitary Body* in the brain, and the *Supra-renal Capsules* just above the kidneys.

Lastly, there is a remarkable adjustment which takes place whenever anyone living near the sea-level changes his residence for another several thousands of feet higher up. The air being now much rarer, contains considerably less oxygen per cubic foot, and the problem therefore is, How to obtain the same quantity of the latter in a given time as before? This is done, not, as might be supposed, by any hurrying up of the breathing, but by the production of an increased number of red-blood corpuscles, so that as the blood courses through the lungs there shall be more of them to absorb the oxygen and carry it away to the tissues.

Once more I would call attention to the purposiveness of all these wonderful and most elaborate arrangements. Are we to believe that they have been brought about merely as the result of the occurrence of a number of chance variations combined with the working of Natural Selection?

CHAPTER IX

MOVEMENT

IN the three preceding chapters I have endeavoured to give a brief account of the Digestive, the Respiratory, and the Circulatory Systems. Each of these is composed of a number of organs, often differing widely from one another in both structure and function and yet so banded together as by their united action to fulfil a common purpose. But this banding together, this conspiracy, so to speak, which exists among the organs of any one of the above systems, is only paralleled by the conspiracy which exists among the systems themselves. The preparation and absorption of the various kinds of food, the taking in of free oxygen—an act which we repeat more than 20,000 times a day—and the subsequent very rapid conveyance of both food and free oxygen to all parts of the body, are not so many independent functions, but, along with the subsidiary function of excretion, serve the one great purpose of maintaining the life of the organism as a whole. They may fitly, therefore, be grouped together under the general head of *Maintenance*.¹

If, however, it should be asked, To what end is the organism thus maintained? What ultimate purpose is subserved by it?—it would be difficult at this stage in our inquiries to give more than a provisional answer. It will be enough perhaps to say here that it is maintained for the sake of enabling continual interaction to take place between the Self or Ego—or by whatever other name we may choose to call it—and the external world. Now the external world acts upon us by means of our various sense organs—the eye, the ear, and the general surface of the

¹ See beginning of Chapter VI, p. 57.

body, etc.—while we in our turn act upon the external world by means of our organs of motion, principally, that is, by means of our muscles. To these must be added a third set of organs, viz. the brain, the spinal cord, the various ganglia, and the nerves, the primary business of which it is to bring into intimate relation with one another the organs of sense and the organs of motion, and to enable us—I am assuming that the will is free—to exercise some sort of real control over our actions. Thus under the general head of “Interaction with the Environment” may be grouped together the three great functions of Movement, Sensation and Co-ordination and Control, all dependent upon, and working in harmony with, one another in much the same manner as Digestion, Respiration, and Circulation. These last, however, seem to occupy a considerably lower plane, seeing that in Man at least their sole *raison d’être* would appear to be to render the functions of Interaction possible.

The muscles by which our various movements are performed differ greatly from one another in size, shape, and general arrangement, but they are all alike contractile—that is, they possess the property of suddenly shortening themselves in consequence of certain impulses reaching them from the brain and spinal cord along the nerves. As already explained, this activity of theirs involves the expenditure of a considerable amount of energy—energy which is set free by the combustion of the food materials brought to them by the blood.

There are two principal kinds of muscles: *Voluntary* muscles, which, as their name implies, are under the control of the will and which have chiefly to do with our external movements; and *Involuntary* muscles, like those which surround the food canal. As seen under the microscope they differ from one another in their minute structure, and they both differ from a third variety, which is found only in the walls of the heart.

A voluntary muscle is built up of a large number of more or less parallel fibres,¹ each of which is about $\frac{1}{500}$ th

¹ There are said to be more than half a million of them in the “biceps” muscle of each arm. For illustration see Chapter XIII, fig. 17, p. 163.

of an inch across, though it may often measure an inch in length. When magnified these fibres present a curiously striped appearance, as though they were composed of a succession of superimposed discs alternately bright and dark. This appearance undergoes certain remarkable changes, at present but imperfectly understood, whenever a muscle contracts.

By its contraction the two extremities of a muscle are necessarily brought nearer together, and hence, if they are attached to bones working on one another at some intermediate joint, the bones themselves will move, or at least one of them will do so, should the other remain fixed. It is thus that nearly all our voluntary movements are performed, of which perhaps we have the best illustration in the movements of the various parts of our limbs. Again, muscles are often attached to the bones which they actuate, not directly, but by means of those extremely tough white glistening bands known as *Tendons*. Of these we have a good example in the so-called hamstrings which may be felt on either side just behind the knee, and which are the tendons belonging to certain important muscles on the back of the thigh concerned in bending the joint.

Among tendons the following are of especial note, seeing that their peculiarities are such as at least to suggest the idea of some intelligent cause having been at work :—

(a) The tendon of the muscle known as the *Superior Oblique*, which serves to rotate the eyeball. Its peculiarity lies in the extraordinary circumstance that it works pulley-wise through a kind of loop fixed firmly to one of the bones of the skull.

(b) The tendon of the *Digastric Muscle*, which is situated in the neck and which materially assists in opening the mouth. Unlike other tendons, it occupies in the muscle a curious middle position dividing it into two distinct portions, and in addition to this it pierces in its course another muscle, viz. the *Stylo-hyoid*. This arrangement, combined with the fact that the two portions are set at an obtuse angle to one another, is obviously—as an examination of the

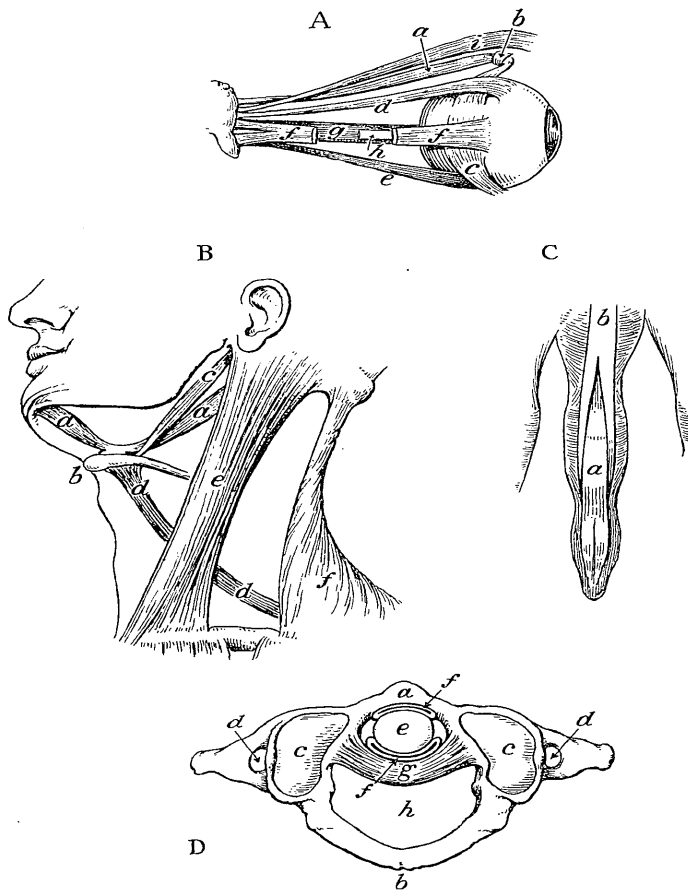


FIG. 8.—A. The Right Eye and its Muscles. *a*, Superior Oblique; *b*, Loop, through which it works pulley-wise; *c*, Inferior Oblique; *d*, *e*, Superior and Inferior Recti; *f*, External Rectus, with piece cut out to show *g*, Internal Rectus, and *h*, Cut end of Optic nerve; *i*, Elevator of eyelid.
 B. Left side of neck with certain muscles. *a*, Digastric muscle; *b*, Hyoid bone; *c*, Stylohyoid muscle; *d*, Omo-hyoid; *e*, Sterno-cleido-mastoid; *f*, Trapezius.
 C. Middle finger of left hand, palmar side, showing the long tendon, *a*, passing through the slit in the shorter one, *b*.
 D. The Atlas (uppermost vertebra) as seen from above. *a*, front; *b*, back; *cc*, where it articulates with the skull; *dd*, Apertures for the passage of the vertebral arteries into the skull and to the brain; *e*, Odontoid process or projecting head of the Axis (second vertebra), which forms the pivot round which the skull and the atlas rotate; *ff*, Synovial sacs; *g*, Transverse ligament; *h*, Aperture through which the spinal cord passes up to the brain.

different parts will show—for the purpose of enabling the lower jaw to be more effectively pulled down.

(c) The tendons of the muscles which bend the finger-joints, each finger being furnished with a pair of them. The longer one of each pair proceeds nearly to the fingertip, where it ends by being inserted into the last of the little line of bones, whilst the shorter tendon proceeds only as far as the last bone but one. Now we should naturally have expected the first of these to be the more superficial of the two—to lie, that is, nearest the skin—whereas on the contrary it is the more deeply placed. The result is that, in order to reach its point of insertion, it has to pass through a slit specially provided for it in the shorter overlying tendon. Apparently the object of this arrangement is to keep the two tendons in their proper positions, but whether that be the case or not, the device is of so remarkable a character as at any rate to suggest the idea of some contriving agent.

From what has been said, it is obvious that under the general title of “Organs of Movement” we must include not only the muscles, but their tendinous terminations, also the bones to which they are attached, and the various and often very remarkable arrangements still to be described in connection with the joints. For if there were no joints and all the bones were rigidly fastened together like those of the skull, clearly there would be no possibility of movement.

There are considerable differences amongst these joints. In some, in which the movement permitted is only very slight, the neighbouring bones are united by a stiff but more or less yielding piece of cartilage, as in the case of the vertebræ, twenty-four of which are joined together in this way so as to build up the greater part of the vertebral column. The ability, therefore, to bend the back depends on this circumstance, a thin cartilaginous disc having been inserted between each pair of contiguous vertebræ. To begin with, however—that is, at a very early stage in our individual development—the vertebral column is wholly cartilaginous, as is permanently the case indeed among the

cartilaginous fishes. When subsequently ossification sets in, the remarkable thing is that the process is but partially carried out, those portions only of the original cartilage being converted into bone which are destined to become vertebræ, the other portions remaining as they were. Lower down in the back, however, there is practically complete ossification, five vertebræ uniting into a single solid bone known as the *Sacrum*. The purpose of this is unquestionably to form along with the great hip bones a firm fulcrum for the lower limbs, which in standing and walking have to support the whole weight of the body.

Elsewhere, and especially in the joints of the limbs, a far greater amount of freedom is permitted. The ends of the bones are made movable on one another, and, in order to diminish friction, not only is the head of each capped with a very smooth piece of cartilage, but between the cartilaginous caps there is interposed what may be described as a thin, flattened-out bag, the *Synovial Sac*. The interior of this is filled with a lubricating fluid secreted from the blood and playing very nearly the same part as the oil which we use in our machines for diminishing friction. Again, to keep the articulating bones in their right positions, their ends are surrounded by what is known as the *Articular Capsule*, which is composed of strong fibrous material, and which serves to connect the bones in much the same way as a piece of india-rubber tubing is sometimes employed to connect, say, a couple of glass rods. Further, to render the joint still more secure and to prevent any kind of slipping, the articular capsule is generally thickened here and there with a few specially strong bands or *Ligaments*.

The joints which permit the greatest freedom of movement are of the ball-and-socket variety, like those which we find at the shoulders and at the hips, where the articulating surfaces are spherical in shape. In hinge-joints, of which the last two joints in each finger furnish good illustrations, the amount of movement is much more restricted, the surfaces here being cylindrical. Intermediate between these two types are the double hinge-joints, as, for instance, the one at the wrist which unites it to the forearm. It will

be found on trial that the hand can be moved up and down with respect to the forearm and also from side to side, but that these two movements can only be combined with difficulty. The reason is that in this case the articulating surfaces are not spherical but elliptical in shape, so that a true ball-and-socket movement is impossible.

An extremely interesting joint is the one situated between the *Atlas* and the *Axis*, which are the names given to the two vertebræ immediately below the skull. In nodding the head the movement takes place between the skull and the atlas, which is the upper of the two vertebræ, but in turning the head from side to side the skull carries the atlas with it, and the movement now takes place between the atlas and the axis. That this may be accomplished the axis is provided with a solid upright piece, the *Odontoid Process*, which projects upwards into the front portion of the large space formed by the bony ring of the atlas. Further, the odontoid process is held in position by a strong transverse ligament which enables it to act as a pivot about which the skull and atlas can freely turn. Behind the ligament and through the hinder portion, therefore, of the said space the spinal cord passes up on its way to the brain, while in front of the ligament and both behind and in front of the odontoid process there is a synovial sac. By this arrangement the rotatory movement of the head is rendered possible, and at the same time the spinal cord is protected by the transverse ligament from what might otherwise prove a fatal accident.

In the animals beneath us in the scale of life the external movements performed by the voluntary muscles are almost exclusively concerned with locomotion and with the seizing and mastication of food, whereas in ourselves two very important changes have been made. Our upper limbs have entirely abandoned what must have been their original, their ancestral function, viz. that of walking, and have been transformed into arms which enable us to execute all our various manipulatory movements. Again, the larynx, which forms the upper portion of the windpipe, together with the various parts in connection with the mouth, such

as the tongue, the palate, the teeth, and the lips, have had in addition to their primary duties this further duty imposed on them, viz. that of acting as organs of speech. When we consider the immense influence which these two great changes have had on the course of human affairs, and how utterly different life would have been, if we had been unable to handle things and to put our thoughts into speech, it is difficult for the unsophisticated person to believe that these things could possibly have come about as the mere result of certain blindly working, unintelligent forces.

That our arms were originally organs of locomotion, which in the course of evolution have undergone an important transformation, there can be no reasonable doubt. For, to go no further into the evidence, there is the remarkable correspondence which exists between the bones in the foreleg of an ordinary quadruped—a dog, for example—and the bones in our own arms; and again, there is the correspondence which exists between the bones of our upper and of our lower limbs. Thus the *Humerus*, which is the single bone in the upper part of the arm, corresponds to the *Femur*, which is the single bone in the upper part of the leg, while the *Radius* and the *Ulna*, the two bones reaching from the elbow to the wrist, correspond to the *Tibia* and the *Fibula*, the two bones reaching from the knee to the ankle. Moreover, we have five fingers as well as five toes, and there is complete agreement between them as to the numbers of their respective joints.

The important changes referred to above are as follows: While the bones, muscles, and tendons of the lower limbs have been immensely strengthened to enable them to support the entire weight of the body—two legs now doing the work of four—and the bones of the foot have been arranged for the same reason in the form of a carefully constructed arch, the arms have been modified in such a way as to enable them to reach, grasp and manipulate as many surrounding objects as possible. Thus the ball-and-socket joint at the shoulders has been made to allow of far greater latitude of movement than the ball-and-socket joint

at the hip. If we imagine a hollow sphere having the upper end of the humerus for its centre and the length of the extended arm for its radius, then we could touch with the hand considerably more than half the inner surface of that sphere; and further, by bending the elbow and the wrist we could touch considerably more than half the points within it. But this is a state of things wholly different from what obtains in the lower limbs, where nothing like the same amount of movement is permitted. Again, if we compare our hands with our feet, not only are the fingers much longer and more flexible than the toes, but the thumb, unlike the great toe, has been set on at an angle to the other digits and rendered opposable to them, thereby enabling us to grasp and handle things in a way which would otherwise have been quite impossible. To facilitate this, the bone in the hand which terminates in the thumb articulates at its base with one of the little wrist-bones in a curious saddle-shaped joint, which is convex in one direction and concave in another, and which permits almost as much freedom of action as a ball-and-socket joint. Lastly, that the hand may be applied with still greater ease to whatever may happen to be within its reach, the forearm has been rendered capable of a very peculiar movement which I must now describe. If the right arm from the elbow to the wrist be laid flat on a table with the palm turned upwards and the thumb outwards, then the two bones, the radius and the ulna, will lie parallel to one another, the radius being on the right side and the ulna on the left. It will then be found that without raising the forearm from the table the hand can be turned from right to left through 180 degrees, thereby causing the palm to face downwards. This movement, which is one that we are constantly making, is known as *Pronation*, and in making it the lower end of the radius describes a semicircle round the lower end of the ulna, the latter remaining fixed, with the result that the two bones become crossed. This, however, would be impossible, unless the radius could rotate about its own long axis, which it is enabled to do because at its upper end it is encircled by a strong annular ligament attached to the ulna, in which

it can freely turn round and at the same time be held in proper position. Special muscles, too, running in a more or less oblique direction—the *Pronators*—have been provided for effecting this movement, whereas others—the *Supinators*—have been provided for reversing it. As no such piece of complex mechanism as this exists in the lower limb—the tibia and fibula always remaining practically parallel to one another—we have here only another instance of the wonderful way in which our arms have been adapted for manipulating the various objects around us.

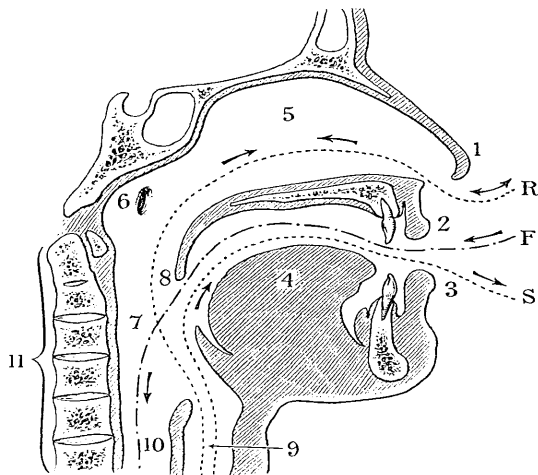


FIG. 9.—Sagittal section of the lower part of the Face. R, Respiratory track; F, Food track; S, Speech track. 1. Nose; 2. Upper lip; 3. Lower lip; 4. Tongue; 5. Nasal cavity; 6. Opening of Eustachian tube to middle ear; 7. Pharynx; 8. Uvula; 9. Larynx; 10. Gullet; 11. Vertebrae.

No less wonderful is the manner in which we have come by our powers of speech. It is extremely doubtful indeed whether we should have been able to speak at all, if it had not been for something which must have occurred far back in those remote ages when the higher Chordates were evolved. For it is one of their peculiarities, to which I

have called attention more than once already,¹ that, in contrast to nearly all the other forms of animal life beneath them, their Respiratory and Digestive Systems have been drawn into closest relation to one another. I refer to the fact that in the pharynx the air-passage leading down from the nasal cavities into the lungs is crossed by the food-passage leading down from the mouth into the stomach.² Now, apart from this arrangement, it is difficult to see how speech could ever have arisen, inasmuch as when we speak we use portions of each of these two passages, and we use muscles belonging to both the Respiratory and the Digestive Systems. With the first set of muscles—the diaphragm, the muscles of the chest, and the muscles of the larynx—we vocalise, we produce sounds; with the second set—the muscles of the tongue, the palate, the jaws, and the lips—we modify these sounds into vowels and consonants. But tongue and palate, jaws and lips, were not primarily intended for this kind of thing; they were intended for the seizure and mastication of food. Similarly, the respiratory organs were primarily intended for respiratory purposes. Yet the two by their conjoint action enable us to speak, providing us thereby with that marvellous instrument by means of which we can express almost every shade of thought and emotion. Nor is this all; for spoken speech in course of time gave rise to written speech, and hence it would appear that even our greatest works of literature, such as Shakespeare's *Plays* and Dante's *Divine Comedy*, owe their origin in the purely physical sense to that intimate connection between the Respiratory and the Digestive Systems which among certain of the higher animals somehow came to be established many millions of years before Man arrived.

SUMMARY

1. Each set of organs belonging to the Digestive, the Respiratory and the Circulatory Systems, though working for an end of its own, conduces thereby to the great end of maintaining the life of the organism as a whole.

¹ See Chapters II and VI, pp. 24, 61.

² This is, strictly speaking, only true of forms higher than the fishes.

2. Similarly, the organs concerned with Movement, Sensation, and Co-ordination and Control, conduce to the other great end of enabling Interaction to take place between the organism and the external world.

3. We can only act upon the external world through our movements, and these we perform by our muscles, which are for the most part excited by certain nervous impulses reaching them from the brain and the spinal cord.

4. Though the muscles are the primary organs of movement, we must class along with them the tendons, the bones, and the various structures connected with the joints, viz. the articular cartilages and capsules, the ligaments, the synovial sacs and their contained lubricating fluid.

5. As tendons possessed of special interest attention may be directed to those belonging to—

(a) The oblique muscles for rotating the eyes ;

(b) the digastric muscles for depressing the lower jaw ;
and

(c) the muscles employed in bending the fingers.

6. Attention may also be directed to the remarkable arrangements in connection with—

(a) The movements of the vertebral column ;

(b) the movements of the head in relation to the vertebral column ; and

(c) the movements of the arms, the hands, the fingers, and the thumbs, including that very unique movement known as pronation.

7. Lastly, as deserving special notice, there is the way in which certain portions of the Respiratory and the Digestive Systems have, in addition to their primary functions, been requisitioned for the production of speech, the great vehicle by means of which one mind communicates with another, and apart from which all the higher reaches of human thought would probably have been impossible.

CHAPTER X

SENSATION

WE have seen in the previous chapter how the energy, originally contained in the sun's rays and afterwards locked up in potential form in the food furnished us by plants, is finally, after the preliminary functions of maintenance have done their work, set free again in the energy of our muscular movements—those movements which enable us to walk, to manipulate objects, and to speak. But these movements would be performed to little or no purpose, they would, though operating on the environment, bear no kind of intelligible relation to it, unless the environment were somehow able to operate upon us and to inform us of the nature and whereabouts of all the various things necessary to our life. Hence the need of those organs of sense which, by the impressions which they convey to us from the outside world, supply us with motives of action and guide us in nearly everything we do.

As in a work like this it would be impossible with any approach to adequacy to treat of all these organs, I propose to confine attention to the eye, the organ of sight, partly because we receive by its means by far the greater portion of our knowledge of the Universe, partly because of the unusual interest which attaches to its various arrangements, and partly for reasons which will appear later on in this book.¹

Now the eye is not simply an organ for receiving impressions of light, in the same way as the skin, among its several functions, is an organ for receiving impressions of heat. It is so constructed as to form a definite, a distinct picture of whatever may be the surrounding scene, enabling

¹ For a brief account of the ear see end of Chapter XVI, p. 221.

us thereby to recognise the shapes and sizes and relative positions of things, as well as their colours and various degrees of illumination. It may be compared, indeed, to an optical instrument, and as such it very closely resembles a photographic camera. Like the latter it possesses a lens convex on both sides, a screen on which to receive images of external objects, a dark intervening chamber, and sundry adjustments for focussing and for admitting more or less light.

In the photographic camera the focussing is done by altering the distances between the object, the lens, and the screen. Let us suppose, for instance, that to begin with the object is a long way off, and that by means of the ordinary rack-and-pinion arrangement the lens has been put at such a distance from the screen—*i.e.* from the ground-glass at the back of the camera—as to produce a clearly defined image. If now the object be brought nearer, the image will become blurred, and it will be found that, to get it clearly defined again, the lens must be moved farther from the screen, that is, towards the object. In other words, as the object approaches the camera, the lens, so to speak, must go out to meet it; if it recedes, the lens must recede in the opposite direction. Now this method of focussing is similar to that which with slight modifications is employed in the case of many of the lower animals, as, for example, in snakes, in several kinds of fishes, and in the octopus. In birds, mammals, and ourselves, however, the method employed is different. To explain this, let us suppose the photographer to be provided with a number of lenses of various degrees of convexity, and also with some ready means for rapidly exchanging them. Then he would find as the distant object gradually drew nearer that, instead of pushing out his lens to meet it, he could still keep the image clearly defined by slipping in lenses one after the other which were more and more convex. Of course that is not exactly what we do in the case of our own eyes, but we do what is practically equivalent to it, for we possess the remarkable power of altering at will the curvature of our lenses, making them more or less convex, according

to the distances of the objects on which we direct our gaze. How precisely this is accomplished will be explained presently.

Meanwhile it should be noted that the image formed by a convex lens is not only inverted, but one in which the right and left sides of the object have, so to speak, exchanged places. I mention the point here, because it is one to which I shall return in Chapter XXII.

In shape the eye is, roughly speaking, spherical, measuring in Man rather less than an inch in diameter. Its front portion, however, which forms about a sixth of the whole, is curved more sharply than the rest and protrudes in consequence.

It possesses three coats. The outermost, known as the *Sclerotic*, is extremely tough, and is commonly spoken of as "the white of the eye."

Its purpose is to enable the organ to maintain its proper shape, and also to afford protection to the far more delicate structures inside. In front, just where the protruding portion of the eye begins, the sclerotic apparently stops, its place being taken by the *Cornea*, although perhaps it would be more correct to say that the cornea is simply a part of the sclerotic which has undergone special modification. It is tough like the sclerotic, but differs from it in its greater degree of convexity, and above all in its transparency. At a short distance behind it comes the *Iris*, which is the coloured portion of

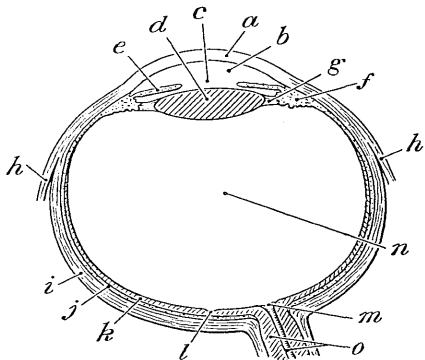


FIG. 10.—Horizontal section of the Left Eye. *a*, Cornea; *b*, Aqueous Humour; *c*, Pupil; *d*, Lens; *e*, Iris; *f*, Ciliary processes and muscle; *g*, Suspensory ligament; *h*, Ends of lateral Recti; *i*, Sclerotic; *j*, Choroid; *k*, Retina; *l*, Yellow spot or spot of perfect vision; *m*, White or blind spot; *n*, Vitreous Humour; *o*, Optic nerve with central blood-vessel.

undergone special modification. It is tough like the sclerotic, but differs from it in its greater degree of convexity, and above all in its transparency. At a short distance behind it comes the *Iris*, which is the coloured portion of

the eye, and which with its central aperture, the *Pupil*, acts as a diaphragm. Immediately behind the iris and in contact with it is the *Lens*.

The middle coat of the eye is the *Choroid*, which is attached throughout the greater part of its extent to the inside surface of the sclerotic, forming a sort of lining to it. If we follow it round, however, towards the front, we shall find, within a short distance of the circular line which marks the place where the cornea begins, that this attachment becomes considerably looser. Also, just here the choroid thickens and is thrown into a number of radiating folds, the so-called *Ciliary processes*, whilst another portion of it is transformed into the exceedingly important *Ciliary muscle*. A little farther in front, at the place where the sclerotic becomes the cornea, the choroid parts company with both of them, and turning inwards becomes the Iris. Thus the middle coat of the eye consists of (*a*) the choroid proper, (*b*) the ciliary processes and the ciliary muscle, and (*c*) the iris. It is only interrupted at two points, viz. at the back of the eye where the optic nerve passes out of the eyeball, and in front of the eye at the pupil, where it is, of course, wanting.

The function of the choroid proper is to keep the eye continually supplied with nutriment, and to this end it is abundantly supplied with blood-vessels. In fact, it is little more than a mass of extremely minute capillaries which are in communication with the general blood system of the body by means of a number of small arteries and veins which pierce the sclerotic at various points on its hinder surface.

The innermost coat of the eye is the *Retina*, the actual screen which receives the images of external objects thrown upon it by the lens. It is a transparent and exceedingly delicate membrane, not more than $\frac{1}{125}$ th of an inch thick even at the thickest part. It lines the choroid just as the choroid lines the sclerotic, and is continued forwards to within a short distance of the ciliary processes. At the extreme back of the retina, and forming part of it, is the so-called *Yellow spot*, which is about $\frac{1}{34}$ th of an inch in

diameter. It is the area of perfect vision, and always receives the image of that particular part of the external scene at which we are directly looking.

Thin as the retina is, it is composed of no less than eight—some say ten—distinct layers. The hindmost of these is the black *Pigment layer*, and immediately in front of it comes *the layer of the Rods and Cones*, the number of which runs into at least six figures. These are the true organs of sight, or rather they are the organs by which the ethereal vibrations of light are converted into those nervous currents which on reaching the brain enable us at last to see. And here it is to be observed that what we objectively speak of as light never penetrates into the dark interior of the skull itself; it never reaches the actual brain; this is only done by the nervous currents. These, though travelling at a speed some $2\frac{1}{2}$ million times less than that of light, and in many other ways differing from it entirely, nevertheless awaken in us the *sensation of light*, just as certain other nervous currents reaching the brain from the internal ear awaken in us the sensation of sound.

Without going into too much detail, it will be enough to state that the rods and cones are in communication with the brain by means of an immense number of nervous fibres—half a million of them, it is said, to each eye—the minute structure of which will be described in the next chapter. Starting from the rods and cones, they run first in a forward direction, that is, towards the lens, but on reaching the front layer of the retina they turn through what is virtually a right angle and make for a certain spot on the retina—the so-called *White spot*—which is situated a little to the nasal side of the yellow spot above mentioned. Here they turn through another right angle and gather themselves up into a thick white cord, the *Optic nerve*, which proceeding backwards on its way to the brain pierces the two outer coats of the eye, and shortly afterwards enters a little bony tunnel specially hollowed out for it in the base of the skull. Seeing now that at the white spot all the other structures above mentioned have to stand aside to allow free passage to the nerve, it follows that at this place

there are no rods and cones, and consequently the spot is blind.

That this is so may be proved by the following experiment. On a book with a dark cover place two shillings in a horizontal line six inches apart with a threepenny-piece

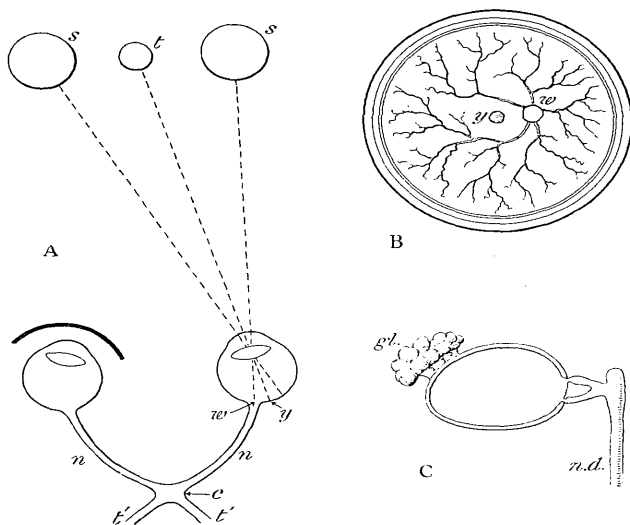


FIG. 11.—A. *s s*, Shillings; *t*, Threepenny-piece; *w*, White or blind spot at entrance of optic nerve; *y*, Yellow spot; *nn*, Optic nerves; *c*, Optic chiasma; *t' t'*, Optic tracts.

B. View of right retina from front. *w*, White spot; *y*, Yellow spot.

C. Right Eye. *gl.*, Tear gland; *n.d.*, Nasal duct.

half-way between them. Close the left eye and with the right look fixedly at the threepenny-piece. It will be found on trial that when the head is held at the correct distance—somewhere between seven and nine inches from the book—the shilling on the right will disappear. The reason is that though the image of the threepenny-piece is now falling on the yellow spot, or spot of perfect vision, the image of the right shilling is falling on the white spot, where there are no rods or cones to receive it. If now, without shifting

one's head, the right eye is closed and the left eye directed on the threepenny-piece, the left shilling will similarly disappear. An inspection, however, of the accompanying diagram will explain matters far better than any verbal description, and it will explain also why the images of the three coins are thrown on the retina in the reverse order. It is because the rays of light cross over in the lens from side to side. I may add that for the success of the experiment it is necessary that the line joining the eyes should be parallel to the line passing through the coins.¹

The retina is supplied with blood not only by the capillaries of the choroid, but by a small artery which with its accompanying vein courses along the centre of the optic nerve. On arriving at the inner, that is, the front surface of the retina, it breaks up into a number of ramifications, the shadows of which, as cast upon the layer of the rods and cones, may be distinctly seen in one's own eye. This is best done by going into a darkened room and moving a lighted taper slowly up and down within a few inches of the right eye, at the same time closing the left. It is well to hold the taper not directly in front of the eye but a little to the side, when not only will the branching system of minute blood-vessels stand out projected on the darkness, but the yellow spot will become visible as a slight depression at a short distance to the left of the point from which the vessels appear to radiate. This latter point marks, of course, the position of the white or blind spot. It is interesting, too, to take note of the fact that the apparent relative positions of the two spots as viewed in this experiment is the reverse of the true one, because the mind always somehow reinverts the image thrown on the retina, and also causes its right and left sides again to exchange places.

Another interesting fact in connection with the retina is the extreme smallness of many of the images cast upon it. Thus the retinal image of the full moon as seen by the naked eye is only about $\frac{1}{150}$ th of an inch in diameter—that

¹ If the book is rotated about the threepenny-piece as centre, so that these lines are no longer parallel, both shillings will come into view.

is, considerably smaller than one of the minute dots inside this circle —and yet it is possible by means of such an image to make out a fair amount of detail on the moon, as, for instance, its so-called *seas*. Again, two parallel lines $\frac{1}{100}$ th of an inch apart, such as can quite easily be perceived as double at a distance of twelve feet, must be represented on the retina by parallel lines with a space less than $\frac{1}{20000}$ th of an inch between them.

The pigment layer, which in the retina comes immediately behind the layer of the rods and cones, serves the purpose among others of absorbing any stray light which might possibly enter in to spoil the purity and definition of the picture. For the same reason nearly all our optical instruments are blackened inside.

The lens, the centre of which is about a fifth of the distance back from the cornea to the retina, divides the general cavity of the eye into two chambers. Of these the anterior is filled with the *Aqueous humour*, which, as its name implies, consists chiefly of water. The posterior and much larger chamber is occupied by the *Vitreous humour*, which is of a jelly-like consistency. Both these humours, as well as the cornea and the lens, are transparent, for the obvious purpose of allowing the rays of light to reach the retina without obstruction—a significant fact, seeing that nowhere else in the body are transparent structures to be found. Further, that their transparency may not be interfered with by the ramifying through them of numbers of little vessels containing blood, the aqueous and vitreous humours receive their nutriment from the so-called *Intra-ocular fluid*, which is as transparent as they are, and which, like all other such fluids, is derived from the blood.¹ It also assists in keeping the eyeball tense.

The lens is held in its proper position immediately behind the iris by means of the *Suspensory ligament*, a thin, transparent circular membrane, the outer circumference of which is fastened to the back of the ciliary processes. Its

¹ At a certain stage in the development of the human embryo the vitreous humour contains blood-vessels, which disappear, however, previous to birth.

central portion is split into two layers, forming a kind of bag, and in this bag the lens is enclosed. But the ligament serves another purpose. Being tightly drawn, it has the effect of compressing the lens and of reducing thereby the convexity of its anterior surface. Now the relation between the degree of convexity thus obtained and the distance of the lens from the retina is such, that in the case of all normally sighted persons the eye is in this way correctly focussed for all distant objects—that is, for all objects more than a few yards away. When, however, it is desired to look at nearer objects the eye has to be *accommodated*, which means that the convexity of the lens must be increased. This is effected by means of the ciliary muscle, which by its contraction drags the ciliary processes and the front portion of the choroid forward, thereby slackening the suspensory ligament attached to them. But this slackening of the suspensory ligament relieves the pressure on the lens and enables the latter, as it is of an elastic material, to recover more or less of its natural convexity. Thus it is that we have the power of focussing our eyes according to the distances of the various objects at which we look, and it is hard to say at which to wonder most—the curious elaborateness of the method employed, or its very marked purposive character. How comes it about, we naturally ask, that there should be a lens in the eye at all; that along with the cornea and the two humours it should be transparent, not opaque; that it should be convex, no other shape of lens being capable of producing images; that it should be provided with a screen; that it should be set at such a distance from this screen that the images cast upon it should be distinct; that it should be held in its proper position by a special very peculiar ligament; that the tension of this ligament should be controlled by a muscle so placed as by its various degrees of contraction to adapt the focus to objects at different distances off; and, lastly, that the lens should not be rigid, like an ordinary lens of glass, but compressible—a condition apart from which most of the foregoing arrangements would be rendered useless? Now it is the concatenation of all

these circumstances which calls for an explanation which shall be truly adequate.

Another remarkable adjustment is the one by which the amount of light entering the eye is regulated according to the degree of external illumination. If in a dark room the flame of a candle be brought near, the pupil, acting as a diaphragm, will automatically contract, but will dilate again as soon as the flame is removed. Not only so, but the pupil of the other eye will contract and dilate in sympathy with it, though it may not itself be exposed to any change of illumination. Again, contraction of both pupils will take place if one's gaze is suddenly transferred from a distant object to a near one. To effect these movements there are two sets of muscular fibres embedded in the iris. One of them, a circular set and closely surrounding the pupil, causes the latter to diminish in size, whilst the other set, a radiating set—radiating like the spokes of a wheel—causes it to dilate. These two sets of fibres are actuated, as well as the fibres of the ciliary muscle, not by the optic nerve, but by a number of much smaller nerves, which pierce the hinder part of the sclerotic and run forward to their destination between it and the choroid. Whereas, however, the ciliary muscle is to a certain extent under the control of the will, it is otherwise with the muscular fibres in the iris. Their action is purely involuntary, and it is brought about, not as might be supposed by any direct influence of the light upon them, but by a message, so to speak, which is dispatched by the retina to the brain via the optic nerve, and which is immediately returned to the iris via the smaller nerves just referred to. At the same time a similar message is sent by the brain to the other eye, causing the pupil there to contract or dilate accordingly. We have here an excellent example of what is known as a *reflex action*, although of course it must be understood that by "messages" in this connection all that is meant is transmission of nervous currents.

The extreme delicacy of the various mechanisms now described renders it necessary that the eyes should be thoroughly well protected. For this purpose two large

bony cavities, the *Orbits*, have been provided for their reception in the front part of the skull. They are conical in shape, with their pointed ends directed backwards and each terminating in the little bony tunnel which, as before explained, affords passage for the optic nerve. There is also a wide cleft at the back of each orbit for admitting the nutrient blood-vessels and the smaller nerves just mentioned. Thus the orbit contains not only the eye itself but a number of auxiliary structures, including several muscles, which will presently be described, and a quantity of fat for filling up all the interstices. This fat serves to protect the eye from injury in much the same way as cotton-wool or hay or some other soft packing material is often used to protect a fragile article when sending it to a distance. Again, to guard it against any accident in front, the eye is furnished with a couple of *lids*, which can be opened and closed at will by means of two muscles set apart for the purpose. Also, to keep out particles of dust each lid is fringed with a row of eyelashes.

But the eyes, or rather their exposed front portions, must be cleansed as well as protected. So not far from the outer corner of each the *Tear gland* is placed, which is continually pouring out its watery secretion over the surface of the cornea. This secretion is drained off at the inner corner by two small channels which deliver into the cavity of the nose, and, to prevent under normal conditions any actual shedding of tears, *i.e.* overflow at the eyelids, the edges of the latter are smeared over with a slight amount of grease, which is secreted by a number of minute glands, the so-called *Meibomian glands*. Moreover, the tears are said to have a poisonous effect on bacteria—another remarkable provision.¹

The eyes are not fixed; they can be turned about, rotated in different directions, upwards, downwards, to the right, and to the left. To effect these movements each is provided with six muscles—four *Recti* and two *Obliques*. The recti are attached behind to the inner surface of the orbit, near the place where the optic nerve leaves it on its way

¹ Starling's *Principles of Human Physiology*, p. 594.

to the brain. In front they are attached to the outside of the eyeball, one to its upper surface, another to its lower surface, and the remaining two to its two sides. Hence the names which they have received—the superior, the inferior, the internal and the external recti. It might be thought, therefore, that these four would be sufficient to produce all the required movements. And so probably they would, if the axes of the orbits were parallel to one another instead of converging as they do towards the back. Because of this convergence the tendency of the superior rectus is not only to turn the eye upwards, but to turn it slightly inwards, a deviation which has to be corrected by a simultaneous contraction of the inferior oblique. Similarly, the tendency of the inferior rectus is not only to turn the eye downwards, but to turn it inwards, a deviation which has to be corrected by a simultaneous contraction of the superior oblique. The internal and external recti, however, call for no such correction (see fig. 8).

Thus altogether each eye is provided with no less than eleven different muscles—(a) three inside the eyeball, viz. the ciliary muscle and the two muscles for regulating the size of the pupil and the amount of light; and (b) eight outside the eyeball, viz. two for opening and shutting the lids, the four recti and the two obliques. As to the last, it will be remembered that the superior one works pulley-wise through a kind of loop (see Chapter IX).

In many mammals, the guinea-pig and the rabbit, for example, the eyes are set so very much to the side of the head that the pictures formed on the two retinas are practically quite different, and so we get what is known as *Panoramic vision*.

Among the carnivores, the monkey tribes and ourselves, the eyes are so far brought round to the front as to make the two pictures almost identical, and so we get what is known as *Stereoscopic vision*. The pictures, however, in the latter case are not quite identical, the extent of the difference between them necessarily increasing as the object looked at is brought nearer. This, combined with the fact that the nearer any object is brought, the greater must be

the convergence of the two eyes upon them—a convergence effected by the conjoint action of the two internal recti—enables us to judge as to how far off the object is, as also to convey to us an impression of its solidity. Close one eye and look at the various articles of furniture in the room, and their solidity will apparently have vanished—they will look like so many differently shaped patches of colour spread out on a flat surface. On the other hand, it is possible by means of a stereoscope to make two really flat pictures combine and produce an illusion of solidity.

Stereoscopic as compared with panoramic vision must undoubtedly be regarded as a higher development, inasmuch as it helps us to perceive the three-dimensional character of space. To render this possible, the bony cavities containing the eyes had to be shifted round to the front of the head, and the relative directions of their two axes had to be considerably altered. It also necessitated a most remarkable rearrangement of the fibres of the two optic nerves at the *Chiasma*, the place where they cross one another just inside the skull. But on this matter more will have to be said in a later chapter (XXV).

SUMMARY

That our movements might be intelligently performed and directed to specific ends, organs of sense became necessary. In this chapter for various reasons the eye has been specially chosen for description. The following is a list of its chief purposive structures:—

1. The Retina, for acting as a screen to receive images of external objects.
2. The Pigment layer at the back of the retina, for absorbing any stray light which may have wandered in.
3. The Lens, biconvex in shape and of just the right degree of curvature, for forming the required images.¹
4. The Suspensory Ligament and the Ciliary muscle, for

¹ In this the cornea, which is also convex, assists.

holding the lens in position and for focussing it, the lens itself being compressible.

5. The Iris with its two muscles, for regulating the size of the pupil, by which more or less light is admitted.

6. The Sclerotic, for keeping the eye tense and for protecting all the delicate structures inside.

7. The Orbits and their contained fat, and the Eyelids with their opening and closing muscles, for protecting the eyes externally. Also the Eyelashes.

8. The Tear glands and the Meibomian glands with their respective Secretions, for cleansing the eyes and preventing overflow. Also, the Nasal canals and cavities, for draining the tears away.

9. The six Muscles—the four Recti and the two Obliques—for rotating each eye in various directions.

10. The Choroid and Retinal Vessels, for supplying each eye with blood. Also, the Intra-ocular fluid, which takes the place of the blood in the transparent parts in front of the retina.

11. The Optic nerve, for conveying visual impressions to the brain, and the other smaller nerves, for actuating the eleven muscles in connection with each eye and for controlling the secretion of the tears.

12. The Bony Channels by which these blood-vessels and nerves gain access through the floor of the skull into the interior of each orbit.

13. The special arrangements by which stereoscopic vision has been rendered possible, so that space may be perceived to be three-dimensional.

14. Added to the above is the almost perfect transparency of the various media through which the light has to pass, viz. of the cornea, the lens, the aqueous and the vitreous humours, and all the front layers of the retina itself, such transparency being found nowhere else in the body.

Further Note.—In snakes and among the Amphibia the lens, as in ourselves, is normally focussed for distant objects. They possess, however, no ciliary muscle, but to adjust their eyes for near objects their lenses are pushed forward

by means of pressure brought to bear on the vitreous humour. In the bony fishes, on the contrary, the lens is normally focussed for near objects, while for more distant ones it is drawn backwards by a special muscle attached to it behind. In this case, therefore, the method resembles much more closely the one employed in the ordinary photographic camera.

CHAPTER XI

CO-ORDINATION AND CONTROL

WE have seen in the last two chapters how it is the function of the muscles to perform movements, and of the organs of sense to report continually as to the state of things in the immediate environment. But muscles and organs of sense must somehow be brought into relation with one another, if the movements in question are to be directed to specific ends, and if that rapid interaction is to take place between an organism and its surroundings which is so characteristic a feature of all the higher forms of animal life. Hence the need of a nervous system to act as an intermediary between the two sets of organs, and by its co-ordination of them to open up the way for still higher developments.

With plants it is different. As it is their chief business in the general economy of things not to expend energy but to store it up, not to exercise activity but rather to provide animals with the means of doing so, we find that they have evolved neither muscles nor organs of sense, and still less have they evolved anything in the nature of a nervous system.¹ They can respond, it is true, though but slowly, to the outside influences of light and gravity, of heat and moisture, but they are quite unable like animals to adjust themselves at a moment's notice to swiftly occurring changes in their environment. Many of them can protect themselves against injury by means of thorns and prickles and various poisonous secretions, but they are powerless to ward off a sudden blow or to make good their escape from an enemy. All this is of a piece with what has been their tendency from the beginning, viz. towards a sedentary

¹ But according to Bosc this statement requires modification.

mode of life, whereas among animals the tendency has always been in the opposite direction, towards ever-increasing activity¹—an activity, however, which has only been rendered possible by their acquirement of special organs of

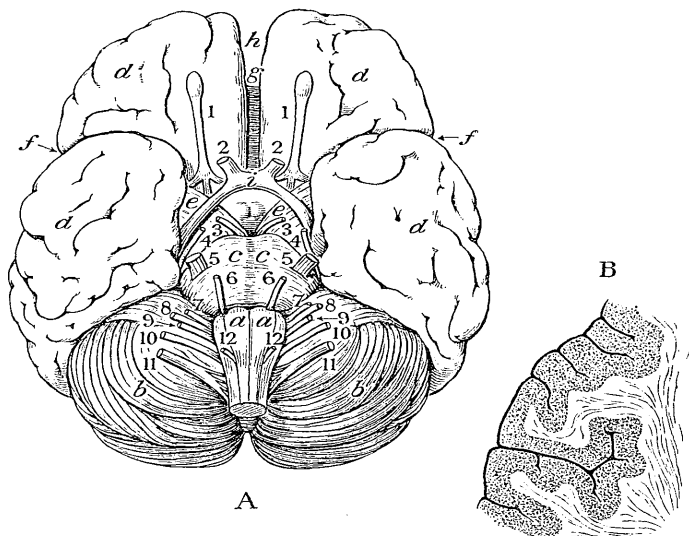


FIG. 12.—A. View of Brain from below. *a, a*, Medulla oblongata, or Bulb; *b, b*, Cerebellum; *c, c*, Pons; *d, d, d, d*, Cerebral Hemispheres; *e, e*, Brain-stalks; *f, f*, Fissures of Sylvius; *b*, Part of the Longitudinal Fissure; *i*, Optic chiasma. 1 to 12, Cranial nerves; 1, 1, Olfactory nerves; 2, 2, Optic nerves; 3, 3, 4, 4, 6, 6, Controlling movements of the eyeballs; 8, 8, Auditory nerves; 10, 10, Vagi.

B. Piece of Cerebral Hemisphere, seen in section and showing how the grey matter dips down into the furrows.

sense and of movement, and, above all, by their acquirement of a nervous system.

In Man and in the Chordates generally the nervous system consists of the *Brain*, the *Spinal cord* and a vast number of ramifying *Nerves*, with here and there peculiar little swellings on them known as *Ganglia*. The brain is

¹ See Chapter IV, p. 38.

enclosed in the cavity of the skull, and for still further protection is wrapped about by three distinct membranes. The outermost of these is tough and fibrous, the inner ones are of a more delicate texture, while the spaces between them are filled with special fluids.

When the brain is viewed from below it is easy to distinguish in it the following parts. First, there is the *Bulb* or *Medulla*—a kind of prolongation of the spinal cord which just here passes up into the interior of the skull through a large oval aperture in its base. The bulb is somewhat conical in shape, its broader end being directed upwards, and it is marked externally by a few longitudinal ridges. Though it is not more than about an inch long it is one of the most vital parts of the body, seeing that it gives rise to the *Vagus nerves*, which control the movements of the heart and of the digestive and the respiratory organs. Immediately above the bulb comes the *Pons*, which is striated horizontally and is joined on behind to the *Cerebellum* or *little brain*. The latter is superficially grey in colour, and is thrown into a number of narrow ropelike convolutions, the majority of which run from before backwards and are more or less parallel to one another. The three parts just mentioned, namely, the bulb, the pons and the cerebellum, together constitute what is known as the *Hind-brain*.

The *Mid-brain* is much smaller, and is represented in the diagram by a pair of gradually diverging white masses known as the *Crura Cerebri* or *brain stalks*.

The *Fore-brain*, which in Man is considerably larger than all the other parts put together, consists mainly of the right and left *Cerebral Hemispheres*. Like the cerebellum they are externally of a grey colour, and they present a number of complicated sausage-like convolutions which are separated from one another by more or less deep furrows. Two of these furrows are well marked, and are known respectively as the *fissure of Sylvius* and the *fissure of Rolando*. The former is a cleft running backwards in a horizontal direction from the neighbourhood of the ear, while the latter, not shown in the diagram, is a cleft running down some little distance vertically from the top. In addition

to these there is the great *longitudinal fissure* which divides the two hemispheres from one another. The grey substance, of which in part the hemispheres are composed, extends to a depth of not more than about the fifth of an inch from the surface, dipping down, however, into all the furrows and faithfully following all their somewhat devious windings. This grey substance is generally referred to as the *Cerebral Cortex*, or more simply as the *Cortex*, and is of quite exceptional interest, as we have every reason to believe that it is the seat of consciousness.

On referring again to the diagram it is easy to make out the origins of the twelve pairs of nerves to which the brain itself gives rise. Of these the most important perhaps are the following: The first or the *Olfactory nerves*, the second or the *Optic nerves*, and the third, fourth and sixth, which are concerned with the various movements of the eyes. The eighth pair are the *Auditory nerves*, and the tenth are the *Vagi*, previously referred to. All these make their exit from the skull by means of little openings tunnelled out for them in its floor. It will be observed that shortly after leaving the brain the optic nerves unite, but only to separate again, thereby forming a sort of St Andrew's cross. This is the *Optic Chiasma* alluded to in the last chapter, and so called from its resemblance to the Greek capital letter Chi.

If now a vertical section be made of the brain, passing through it from front to back,¹ a minute canal will be seen which, having come up the centre of the spinal cord, opens up behind the bulb and the pons into a considerable space known as the *fourth ventricle*. From this space a narrow passage, the *Iter*, runs forward through the mid-brain and leads to another somewhat similar space, the *third ventricle*, which communicates with a pair of further spaces, the *lateral ventricles*. These curious spaces with their connecting passages are mentioned here because they will be referred to again in Chapter XVI.

The Spinal Cord, which, as already stated, is continuous with the brain above, is enclosed in a long tube formed

¹ For illustration see Chapter XVI, fig. 27, p. 227.

by a series of arched pieces of bone, which are immovably attached to the hinder part of the vertebral column and are in fact one with it. There is an arched piece to each vertebra. In its downward course the spinal cord gives off thirty-one pairs of nerves, which pass out to the right and left through a number of side openings specially provided for them. Each nerve is connected with the spinal cord by two roots—an *anterior* and a *posterior root*—and on each posterior root there is a small lump or ganglion containing a certain amount of grey matter similar to that found in the brain. Grey matter is also found in the spinal cord itself, and appears in every cross-section of it as an internal mass, in shape somewhat like a butterfly.

The nerves themselves after leaving the spinal cord begin to break up almost immediately into innumerable branches, the ultimate filaments of which find their way into nearly every part of the body, including of course the voluntary muscles and the skin, which in addition to its other functions is the organ of touch. The muscles of the face, however, and of the tongue, and the special organs of sense which, like the eyes and the ears, are situated in the head, are supplied, as we have seen, by pairs of nerves proceeding directly from the brain itself.

To understand the way in which the nervous system works it is essential to gain some acquaintance with its minute structure as revealed by the microscope. We will begin with the nerves.

A nerve consists of a large number of exceedingly delicate fibres, each measuring about $\frac{1}{1000}$ th of an inch in diameter, though in length often extending to several inches or even feet. These fibres run parallel to one another without intercommunicating, and except at their extremities seldom branch. When a nerve itself branches, what happens is that at that point some of the fibres part company with the rest and start off in a different direction, much in the same way as is often the case with a set of telephone wires. In cross-section a nerve is seen to be made up of one or more bundles, each of which contains a large number of fibres, the fibres themselves appearing as so many minute

circles. Both bundles and fibres are bound together by connective tissue, and, ramifying in this last, there are several

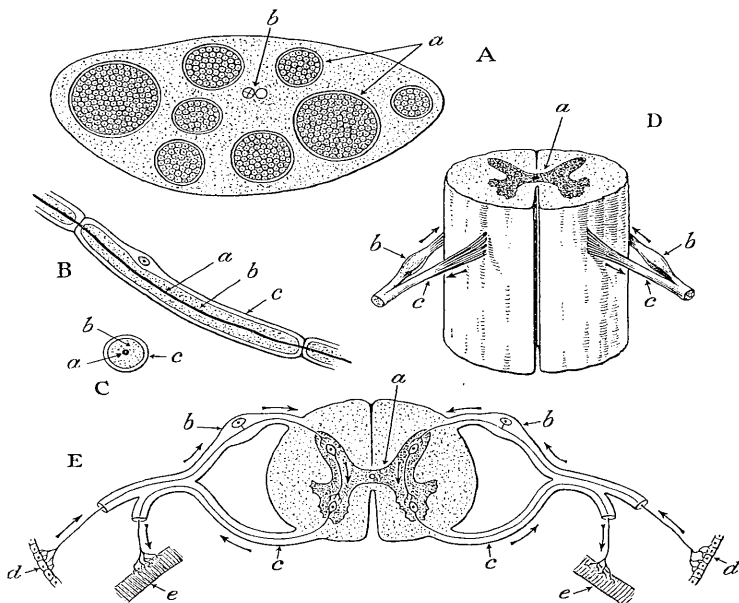


FIG. 13.—A. Cross-section of Nerve, showing *a*, bundles of nerve-fibres surrounded by connective tissue, each fibre represented by a small circle with a central dot, viz. its axis-cylinder; *b*, Nutrient vessels.

B. Highly magnified longitudinal view of nerve-fibre, showing *a*, the axis-cylinder; *b* and *c*, its two sheaths.

C. Cross-section of fibre; lettering the same.

D. Portion of Spinal Cord. *a*, Grey matter with minute central tube; *b*, *b*, Posterior nerve-roots with their ganglia; *c*, *c*, Anterior nerve-roots.

E. Cross-section of Spinal Cord, illustrating Reflex action. *a*, *b* and *c* as in D; *d*, *d*, Termination of fibres in skin (or some other sense organ); *e*, *e*, Terminations in muscles (or glands).

small arteries and veins for supplying the whole arrangement with blood.

In longitudinal section and under higher magnification a nerve fibre can be shown to consist of a central thread

or *Axis-cylinder*¹ surrounded by a couple of sheaths, viz. an inner one, the so-called *Medullary sheath*, and an outer and much thinner one, the *Primitive sheath*. The axis-cylinder is the really essential part of the fibre, as it is the conductor of the nervous currents. The medullary sheath serves, it would appear, a double purpose, viz. that of conveying nourishment to the axis-cylinder and of acting as a kind of insulator, by preventing the nervous currents, as they travel along, from wandering out of their proper course.

As to the real nature of a nervous current nothing is positively known. Its passage along an axis-cylinder has been compared to a current of electricity, but whereas electricity travels with enormous speed, the speed of a nervous current is comparatively very slow—about 300 yards per second—which is considerably less than that of sound. If a man, for example, in London with a sufficiently long arm were to grasp a red-hot iron in Edinburgh, he would not be conscious of any pain till an hour and a quarter afterwards.

The fibres entering into the composition of a nerve are of two kinds. There are the *Outcarrying fibres*, which convey currents downwards to the muscles, causing them to contract, and there are the *Incarrying fibres*, which convey currents upwards, causing sensations—that is, as soon as they reach the cortex of the brain.² Now, although there is no apparent anatomical difference between these two kinds of fibres, there is this interesting fact in connection with them, that closely as they are bound up together along nearly the whole length of an ordinary nerve, they are parted from one another in the two roots by which the nerve takes its origin from the spinal cord.³ Thus the anterior root contains outcarrying fibres only, while the posterior root contains incarrying ones only, with the

¹ The dots inside the minute circles in the figure are the axis-cylinders cut across.

² There are outcarrying and incarrying fibres in addition to those above mentioned.

³ The olfactory optic and auditory nerves naturally consist of incarrying fibres only.

result that, if the former be cut across, the muscles supplied by the nerve will be paralysed, though the nerve will still be able by means of the posterior root to convey impulses upwards, which on reaching the brain may give rise to sensations. On the other hand, if the posterior root be cut across, all feeling will be destroyed in the parts to which the nerve sends branches. Section of the nerve lower down—that is, after the two roots have joined up—will of course destroy in all the parts supplied by it both the possibility of movement and the power of causing sensations.

Not only are all nerves built up of nerve-fibres, but the same is true of all the white portions of both the brain and the spinal cord. With the grey portions it is different, for here intermingled with the nerve-fibres there are the nerve-cells. Formerly the fibres and the cells were regarded as the two elements out of which the entire nervous system was constructed, but their relation to one another is such that, according to the more modern view, there is in the nervous system but one kind of fundamental unit, viz. the *Neurone*. It is important, therefore, to understand clearly what a neurone is.

Briefly stated, a neurone is a *cell*¹ consisting of a *cell-body* and of a number of very fine *processes* or prolongations of its substance reaching out in different directions. The cell-body—which corresponds to what in the older terminology was described as a nerve-cell—varies in size from about $\frac{1}{1000}$ th to $\frac{1}{350}$ th of an inch across. It may be either round, oval, flask-like, pyramidal, polygonal or wholly irregular in shape. Near its centre there is always a roundish, comparatively transparent spot, the *nucleus*, and inside it a much smaller spot, the *nucleolus*.

As to the processes, most of them are very short, and they present when branched—as is usually the case—a somewhat treelike appearance. This branching, or *arborisation* as it is termed, is well seen in the *cells of Purkinje*, which occur in great abundance in the grey matter of the cerebellum. Besides these short processes—the so-called *Dendrons*—each neurone is provided with a special process

¹ The nature of cells is more fully explained in Chapter XIII.

known as the *Axon*, which is generally very much longer. Near the beginning of its course it often gives off a few

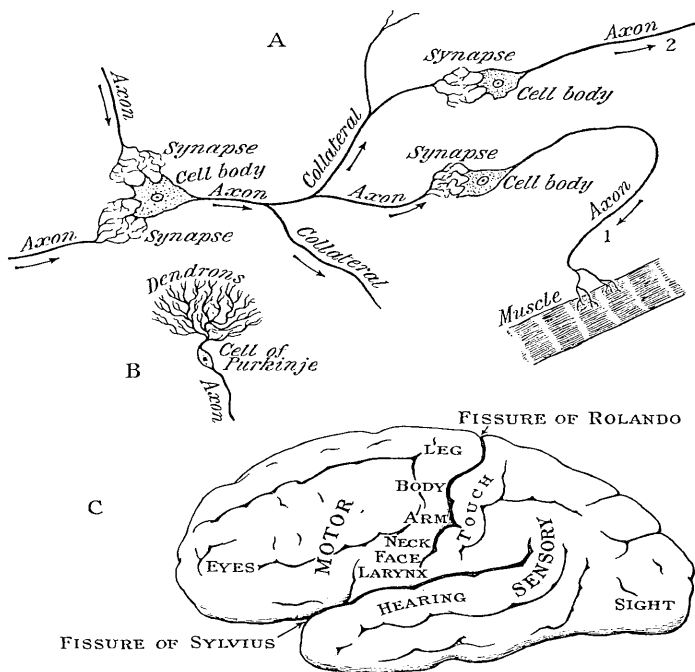


FIG. 14.—A. Diagrammatic view of Neurones and of their connections with one another. Portions of five of them shown. It is thought by some that the Will acts by controlling the passage of the nervous currents at the Synapses. Thus a current might be made to flow in the direction of either 1 or 2.

B. A Cell of Purkinje from the Cerebellum.

C. Diagram illustrating the chief Motor and Sensory areas of the brain. The former are in front of the fissure of Rolando, the latter behind it.

side branches or *Collaterals*, but in any case it ends, as also the collaterals, in a number of minute filaments, in other words, by arborising.

According to what has been termed the *Law of Forward*

Direction,¹ nervous currents always enter a neurone by its dendrons, and after travelling through the cell-body continue their course onwards through the axon and its collaterals, till at last they pass out through the terminal arborisations. It is a question, however, as to whether this law invariably holds.

I have already stated that an ordinary nerve consists essentially of a large number of nervous fibres, and that along the centre of each there runs an axis-cylinder. Now these axis-cylinders—and for the moment I am referring to those only which belong to the outcarrying fibres—are really the axons of neurones, the cell-bodies of which are situated in the grey matter of either the spinal cord or the brain. It is from these cell-bodies and along these axons that the nervous currents travel outwards to the muscles, causing them to contract, as also to the glands, causing them to secrete.

With the axis-cylinders of the incarrying nerves the case is rather different. Each is an axon-like prolongation of a cell-body which is usually situated, not in the spinal cord, but in the grey matter of one of those little swellings or ganglia found on the posterior roots of the nerves. Seeing, however, that in these axis-cylinders the nervous currents always travel upwards, away, that is, from the sense organ and towards the cell-bodies—of which they, the axis-cylinders, are the prolongations—it is best perhaps to regard these last as exceptionally long dendrons. At all events by so regarding them they no longer contradict, as they otherwise would, the Law of Forward Direction. As for the currents themselves, they do not stop at the cell-bodies in the aforesaid ganglia, but passing through them they enter almost immediately the hinder portion of the spinal cord by means of short axons, which after giving off a certain number of collaterals end in the usual manner by arborising.

We have next to consider the way in which the nervous currents are transferred or passed along from one neurone to another. And to do so, we will take as a very simple

¹ J. D. Lickley, *The Nervous System*, p. 7.

illustration what happens when in a frog, whose brain has been destroyed, one of its toes is pinched or otherwise irritated and it twitches its leg in consequence. Now in this action there are at least three different sets of neurones involved. There are, first, the neurones, the greatly extended dendrons of which convey the current from the irritated spot up through the spinal ganglia on the posterior roots into the spinal cord itself. Secondly, there are the neurones, the axons of which, after emerging from the spinal cord, convey the current back to the muscles of the leg, causing thereby the twitching movement. And thirdly, situated entirely in the cord, there is a set of very much shorter neurones which serve to put the other two sets in connection, thus enabling the current to flow freely forward through them all. Obviously, then, there must be at least two different places where the current passes across from one set of neurones to the next. These are known as the *Synapses*, and in the nervous system taken as a whole they exist in enormous numbers. There are two somewhat different varieties of them. Either we find an axon—or it may be a collateral—intertwining its terminal filaments with the filaments or dendrons of a neighbouring cell-body, or else in more direct fashion allowing its filaments to arborise around the cell-body itself. It is a somewhat moot point as to whether at these synapses there is any actual continuity between the neurones, but the evidence would appear to support the conclusion that no such continuity exists. Of course if that is so, we must conceive of the nervous currents as somehow at each synapse leaping across from one neurone to another, in much the same way as an electric current leaps across a short gap in its circuit, thereby producing a spark. Anyhow, it appears that there is always a certain amount of resistance at these synapses; the nervous currents are slightly delayed at them and may even be stopped. On the other hand, by administering certain drugs, such as strychnine, these resistances may be completely broken down.

In the experiment with the frog, as above described, we have what is commonly called a *Reflex action*, because a

current ascending from an organ of sense is turned back or reflected in another and quite different direction. In the contractions and the dilations of the pupil of the eye, as the result of changes in the amount of light admitted, we have already come across a case of reflex action, except that there the reflection takes place in the brain itself instead of in the spinal cord. There are many other instances of the same kind in different parts of the body.

The important thing to remember, however, about these reflex actions is that they are typical of practically everything else which happens in the nervous system, considered, that is, on its purely physical side. For the nervous system, including all its various parts, turns out to be simply one vast highly organised assemblage of neurones, through the dendrons, cell-bodies, axons and collaterals of which nervous currents are continually flowing. Of any other form of activity in the nervous system we know nothing, in so far as physiological investigations can cast light on the subject. It is probable, I may add, that the extremely complicated arrangements of fibres in the cerebral hemispheres may have something to do with the association of our ideas, though not perhaps in the manner generally imagined; ¹ but beyond this there is nothing in the brain or in its mode of activity to suggest all that rich, well-nigh infinite variety of experience, sensuous, intellectual and emotional, which goes to make up our inner conscious life.

Complicated arrangements of fibres like those just referred to are found in the brain, and to a lesser extent in the spinal cord, because in most cases the axons give off several collaterals, and these by means of their terminal arborisations link up several neurones with one another. Hence it follows that a current as it passes along from one neurone to another is often offered, so to speak, a considerable choice of paths. It may proceed this way or that according to circumstances. For instance, if it should happen to be an ascending current arising from some sense organ, it may be turned back or *reflected* at various points in its

¹ See Chapter XXII, p. 314.

upward course—either in the spinal cord, or in the bulb, or in the cerebellum, or in one of the grey masses at the base of the brain, or in the highest region of all, namely, the cortex. It is only, however, in the last-mentioned case that consciousness will be aroused and that any sensation will be experienced.

The white, the non-cortical portions of the hemispheres, are wholly made up, as might naturally be inferred, of an immense number of ascending and descending fibres, the former or sensory ones conveying currents upwards from the organs of sense, the latter or motor ones conveying others downwards to the organs of movement. In addition to these, which are collectively known as the *Projection fibres*, there are the *Commissural* and the *Association fibres*. The commissural fibres are those which connect up with one another the corresponding parts of the cortex on the right and the left sides of the brain. On the other hand, the association fibres, some of them long and some of them short, are those which connect up the different parts of the cortex belonging to the same side.

One of the most interesting and important discoveries in reference to the brain is that each of our sensations—sight, hearing, touch, etc.—has a special area assigned to it in the cortex. Thus the visual area, which receives all the currents streaming in through the optic nerves, is situated in certain convolutions at the very back of the hemispheres. It is, in fact, that particular region in the brain which “does the seeing”; and hence, if it is destroyed or if the fibres in the optic nerves with which it communicates with the eyes are anywhere cut across, blindness ensues. Similarly, there are auditory, olfactory, gustatory and tactile areas, the last being situated in the convolutions immediately behind the fissure of Rolando. In front of this fissure and in close contiguity with one another there are the various motor areas, from which currents travel outwards to the face, to the trunk, and to the upper and lower limbs. In the chimpanzee, one of the anthropoid apes, these motor areas have been carefully mapped out, and there can be little doubt that in Man their general arrangement is practically

the same. It is particularly to be noted that their relative positions are in rough agreement with the relative positions of the various parts of the body to which they supply nerves, except that the order in which they are placed is inverted.

When at the sight of some external object we make movements for its attainment or avoidance, we must suppose, therefore, that the nervous currents, reaching the visual area at the back of the brain and so causing us to see, are somehow transmitted by longer or shorter association fibres to the motor areas in front of the fissure of Rolando, and that thence they are dispatched to the muscles necessary for making the movements in question. In those cases, however, in which we deliberate as to what exactly shall be our line of action, we must suppose that the currents take a more or less circuitous route, gradually making their way through a longer or shorter chain of neurones, and only discharging themselves into the motor areas when we have come to our final decision.

At this point perhaps it may be well to remind ourselves again of the vast number and extreme complexity of the nervous elements composing the hemispheres, and of the impossibility therefore, apart from every other consideration, of predicting the exact routes which the currents arriving in them will pursue. It is different, however, with those currents which, though travelling upwards, are turned aside or reflected before they reach the cortex. They are not only unaccompanied by consciousness, but apparently flow along certain predetermined paths—predetermined, we must suppose, by a certain fixity of conditions prevailing in the synapses across which they have to pass. But it is highly probable that in the cortex itself not only are currents capable in some mysterious way of awakening consciousness, but that consciousness in its turn is capable of determining along which precise paths they shall flow, herein taking advantage of a certain indeterminateness of the nervous connections. If so, we may compare consciousness, or perhaps I should say the Will, to the pointsman who, by simply moving a lever and without adding to or subtracting

from the energy of the passing express, determines along which particular line of rails it shall proceed.¹

Of course, if on the contrary the theory be true, that all our actions are absolutely necessitated and that we can no more help doing them than the earth can help rotating on its axis, what has just been said falls to the ground, and such expressions as "freedom of choice," "freedom of the will," etc., become entirely delusive. Without entering, however, at all deeply into a discussion of the great controversy which has raged for so long around this question, there are just a few considerations which may be mentioned here as bearing on the subject and which would seem to be of weight.

In the first place, although in many of our decisions we are conscious of no particular effort, and it may therefore perhaps be said that we are simply following the motive which happens to be strongest, this does not appear to be always the case. In our more important decisions, and especially when great moral issues are at stake and to do the right involves considerable sacrifice, we are conscious of an inward struggle, at other times unfelt, in which if the higher motive is to prevail, we have—so at least it seems—personally to intervene. As the late Prof. William James has so admirably said : ² "If in general we class our springs of action as propensities on the one hand and as ideals on the other, the sensualist never says of his behaviour that it results from a victory over his ideals, but the moralist always speaks of his as a victory over his propensities. . . . The ideal impulse appears . . . as a still small voice which must be artificially reinforced to prevail." And he adds : "Effort is what reinforces it." Then after putting the question, "What determines the amount of the effort" needed "when by its aid an ideal motive becomes victorious over a great sensual resistance?" he replies by saying : "The very greatness of the resistance itself. If the sensual propensity is small, the effort is small. The latter is made great by the presence of a great antagonist. And if a brief

¹ "Consciousness in a mere automaton would be a useless and unnecessary epiphenomenon."—Lloyd Morgan.

² *Textbook of Psychology*, pp. 443, 444.

definition of an ideal or moral action were required, none could be given which would better fit the appearances than this : It is action in the line of greatest resistance."

Again, if no real choice on our part is at any time possible, and consciousness is powerless to exert any sort of influence on the course taken by the nervous currents flowing through the brain, it is difficult to understand for what end consciousness should ever have arisen, why it should still exist, and why, moreover, it should have reached so remarkable a degree of development in Man. Everything else in the organism, down even to its apparently most insignificant part, has, as we have seen, its purpose—or at least in the case of a vestigial structure has *had* its purpose—whether there has been a supreme Purposer or not. Is consciousness, then, which is undoubtedly one of the highest of Life's products, to be the only exception to the rule—to be an entirely purposeless thing—although strangely enough it is continually, as it would appear, forming any number of purposes of its own ? ¹ Is it not altogether more reasonable to suppose that its function is precisely that of directing and controlling activity, and especially when we bear in mind that in the animal kingdom it has been activity, and activity in ever-increasing power and range and nicety of adjustment, after which Evolution has apparently been striving all along ? ²

Or once more, if our conscious states, including of course our volitions, are simply so many side effects of a chain of purely physical events having their seat in the brain, or if, as some have supposed, they form a series in every respect running parallel to and exactly corresponding with those events, then why should not the brain have undergone all its marvellous structural development and have accomplished by its activity all that it has actually accomplished apart from consciousness altogether ? In that case everything in our human world would outwardly have happened just as it has actually happened. Thus not a brainless, but

¹ See beginning of Chapter V.

² "Our consciousness . . . has in all probability been evolved like all other functions for a use. It is in the highest degree improbable *a priori* that it should have no use."—W. James, *Textbook of Psychology*, p. 103.

a mindless, Shakespeare would have arisen, and mindless of all that he was doing would still have written his plays. Mindless actors for the last three hundred years would have represented these plays on the stage, and tens of thousands of equally mindless individuals, who could neither see, nor hear, nor comprehend what the plays were all about, would have flocked to the theatres when they were being performed. Similarly, human history would outwardly have run precisely the same course which it has, and the great European War would have been fought out to the same final result, but with no knowledge on the part of any of the combatants as to what was happening, and still less of the deep moral significance of the whole terrific struggle.

If, on the other hand, as I am constrained to believe, consciousness has arisen for the express purpose of enabling the organism to control its own activities, we can at once see a meaning in its appearance, and can learn to regard the nervous system, not only as a most complicated piece of mechanism for the co-ordination of sensations and movements, but as a means whereby in the highly developed brain of Man full freedom of choice has at last been rendered possible.¹

SUMMARY

1. The Nervous System consists in Man and in the higher animals generally of the brain, the spinal cord, the nerves with their endless ramifications, and of a number of little bodies known as ganglia.

2. Its primary purpose is to act as an intermediary between the organs of sense and the organs of movement, so that appropriate and rapid responses may be made to all changes in the environment affecting the welfare of the organism as a whole.

3. In spite of the complexity of structure found in the various parts of the Nervous System, it is entirely built up of elements which are essentially all alike, viz. of neurones.

¹ "While the spinal cord transforms the excitations received into movements which are more or less necessarily executed, the brain puts them into relation with motor mechanisms which are more or less freely chosen."—Bergson, *Matter and Memory*, p. 299.

4. A neurone consists of a cell-body and of a number of variously named processes or threadlike prolongations of itself along which the nervous currents flow.

5. Though the rapidity of these currents is far less than that of light or even of sound, it greatly exceeds that of the fastest express train, so that in this respect, if in no other, these currents differ entirely from every other known form of activity in the body.

6. In its onward course a current generally passes through a succession of neurones, leaping across, so to speak, from one to another at certain places known as synapses.

7. Some of these currents flow inwards—that is, from the organs of sense to the spinal cord and the brain, whereas others flow outwards—that is, from the brain and spinal cord to the organs of movement, as also to the secreting glands, etc. To each of these two sets of currents special paths or chains of neurones have been assigned. A third set flow along paths connecting up different parts of the brain and of the spinal cord with one another.

8. Nervous currents only awaken consciousness when they pass through the cortex of the brain, viz. the grey matter forming the outer crust of the cerebral hemispheres. The relations here of the neurones to one another are exceedingly complex, and are characterised by a certain amount of indeterminateness which apparently leaves room for freedom of choice.

9. This freedom of choice may possibly be exercised by the mind acting as a sort of pointsman at the various synapses, by blocking up certain paths and at the same time leaving others open. In this way the nervous currents may be constrained to take the desired direction.

CHAPTER XII

RETROSPECT

IN the necessarily brief account which I have now given of the principal functions of the human body—Reproduction excepted—my chief object of course has been to demonstrate the extraordinary purposiveness of all the different organs concerned, and of the various systems and groups of systems into which they have been built up. It is impossible, indeed, in view of that marvellous wealth of detail which has now been described, to deny that such purposiveness exists. The one question, however, which thrusts itself upon us with renewed insistence is, How has this purposiveness been brought about? Are we to attribute it to some unseen Intelligence of an immeasurably higher order than Man, or must we summarily dismiss such an idea as quite superfluous, seeing that the facts can be perfectly well explained as the result of unintelligent causes alone?

For a full discussion of this very important question it will be advisable to wait till we have advanced somewhat further in our inquiries.¹ There are certain points, however, already in part touched upon in the foregoing chapters which may be profitably dealt with at once, and which would seem in no small degree to strengthen my general line of argument.

And first, if the doctrine of Common Descent is true and all the higher forms of animal life, including Man, are genealogically derived from those extremely simple ones which originally peopled the earth, it may be well to try and realise how enormous is the gap separating the two. So long as we restrict attention to closely related species,

¹ See Chapters XXV and XXVI.

the differences between which are comparatively slight, it might be possible perhaps to account for such differences by the occurrence of variations of a purely fortuitous kind. It becomes, however, quite a different matter when we compare together so highly complicated a structure as the human body with all its wonderfully interconnected parts, and so simple an organism as, for instance, the common *Amœba*; and when we remember that it is from just such a simple organism as the latter, or from one very nearly akin to it, that all the higher forms of animal life are supposed ultimately to be derived. Some short description, therefore, of the common *amœba*, and of the way in which it performs its various functions, may perhaps help us at this point to understand more clearly how vast was the interval which had to be bridged. It may well, too, make us hesitate before accepting straight away the theory, that mere chance, working in conjunction with Natural Selection, was equal to the task of effecting so great a transformation.

The *Amœba*, then, which occupies a position almost at the bottom of the Animal Kingdom, is a minute piece of protoplasm or living slime measuring about $\frac{1}{160}$ th of an inch in diameter, and hence only just visible to the naked eye. It shows no division into such parts as head, trunk and limbs like those which we possess, but is practically shapeless, or rather is continually changing its shape by putting out here and there little protrusions of itself known as *Pseudopodia*. It has neither mouth, nor stomach, nor indeed digestive organs of any sort, but in its usual habitat, which is water, it can take in at any point of its surface whatever particles of food may happen to come its way. These it lays hold of by its pseudopodia, engulfs and immediately proceeds to digest, though in the simplest manner possible, by letting them dissolve in its own semi-liquid interior. Again, it is entirely lacking in any special organs of respiration, taking in its oxygen just as it takes in its food over the whole extent of its surface. Moreover, being so small it is in no need of a circulatory system. Any transport of material which may be necessary is sufficiently accomplished by the curious internal streaming

of its protoplasmic substance. Also, by means of this streaming it is able to put out its pseudopodia in whatever direction it pleases, and at the same time to withdraw them in others, managing in this way to crawl about from place

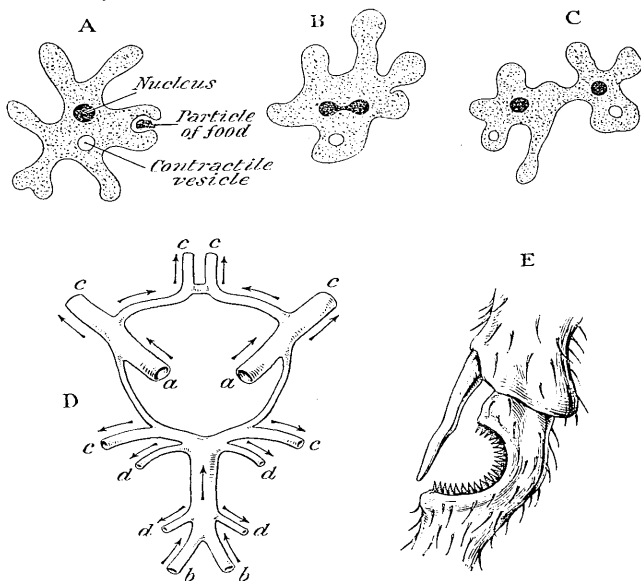


FIG. 15.—A. An Amœba.

B. The same, beginning to divide.

C. Division nearly complete.

D. Circle of Willis. *a, a*, Internal Carotid arteries; *b, b*, Vertebral arteries (branches of the Subclavians); *c, c*, Arteries supplying cerebral hemispheres; *d, d*, Arteries supplying cerebellum.

E. Part of a Bee's foreleg, showing comb.

to place and so effect locomotion. Thus it is entirely without limbs, as we ordinarily understand that term, and without any of those special organs of movement—muscles, tendons, bones, etc.—which were described in Chapter IX. In the higher faculties of sense, sight and hearing, it is again totally wanting, but it is sensitive to touch. Thus it will shrink away on contact with a sharp instrument, and

can apparently distinguish between particles of matter which are good for food and those which are not, and which it consequently rejects. As for any nervous system, there is not the slightest trace of one, nor is there any need for such, seeing that both locomotion and those very simple reactions just referred to can quite easily be performed without it. Lastly, like all other organisms, but once more in an exceedingly simple manner, it can reproduce its own kind.¹

Here, then, is a little animal which somehow contrives in its own very primitive way to discharge all the essential functions of life—self-maintenance, interaction with the environment and reproduction—and yet possesses neither mouth, stomach nor intestines; neither nasal passages, windpipe nor lungs; neither heart, arteries nor veins; neither muscles, tendons nor bones; neither eyes nor ears; neither nerves, spinal cord nor brain. If, then, as the theory of Common Descent requires, Man is really descended from some such simple amœba-like form as this, by what means has all the subsequent and infinitely elaborate internal organisation of his body been gradually brought about? That it took millions of years for its accomplishment does not lessen in the least the well-nigh miraculous nature of the result. Indeed, it is very difficult to resist the impression that we are somehow being taken in and juggled with, when we are asked to believe that what happened stood in need of no kind of conscious superintendence, but was the result solely of certain blindly working physical and chemical forces.

And here, once more, I should like to emphasise the fact, previously noted, that while every organ in the human body has its own very definite purpose to fulfil, the same is true of each of those six systems which we have considered in the foregoing chapters. In each of them we find that the organs composing it are so co-ordinated, as by their united action to accomplish the purpose for which the system as a whole exists. Thus if the teeth are for the purpose

¹ For a fuller account of the Amœba see Bourne's *Comparative Anatomy*, vol. i, p. 129.

of mastication, the salivary, gastric and other glands for the purpose of manufacturing the digestive juices, and the muscular fibres surrounding the alimentary canal for the purpose of propelling its contents continually onwards, all these purposes are conducive to, and alone find their meaning in, the purpose of the digestive system as a whole, viz. that of bringing the food with its various energy-containing substances into that state of solution in which it can most readily be absorbed.

Again, if the organs belonging to any given system are thus co-ordinated, so also are the systems themselves. Digestion, for example, apart from Respiration would do its work in vain, for of what use would it be to dissolve the above-mentioned substances if there were no oxygen available for their consumption and for the consequent release of the energy locked up in them? Or of what use would it be for the oxygen to be supplied, but not the food?

Further, as in all the more highly organised animals a circulatory system is required for the proper distribution of the digested materials and for the swift conveyance of the oxygen to the various tissues, it follows that all three systems—the Digestive, the Respiratory and the Circulatory—are alike necessary, and that although each of them pursues, so to speak, an end of its own, they all work together for the attainment of the one great and far more comprehensive end, viz. the maintenance of the organism as a whole.

It is the same with the three higher functions discharged respectively by the Motor, the Sensory and the Nervous Systems. Differing widely as they do from one another, they too conspire together for the realisation of a common end, viz. that of enabling constant interaction to take place between the organism and its environment. Again, these three higher functions are curiously enough dependent for their performance on the three lower ones, for clearly, apart from the available energy which the latter supply, neither movement, nor sensation, nor nervous currents would be possible. Once more, the lower functions are dependent

in their turn on the higher ones, for if we were deprived of the power to move, and if all the channels by which impressions reach us from outside were suddenly closed, we could neither go for our food, nor have the least notion of the direction in which to go for it.¹ Digestion, therefore, would be in the position of having nothing to digest, and Respiration and Circulation would very soon be brought to a complete standstill.

Thus not only has every organ in the body its own special function assigned to it, but the organs considered as a whole have been so built up into systems, and these latter into still more comprehensive groups, that each such system or group can only discharge its higher and more important function by the continually yielded co-operation of the different organs or associations of organs composing it. And it is precisely this remarkable interweaving of purposes as displayed by living organisms, and the manner in which the lower purposes are carried up and rendered subservient to the higher ones, that perhaps more than anything else demands an explanation which, as I said before, shall be really adequate.

A remarkable illustration of the way in which the various organs minister to one another is afforded by the Circulatory and the Nervous Systems. These two systems, different as they are in every other respect, have this one feature in common, that they are both *ramifying* systems, their ramifications practically extending into every part of the body. And this makes their relations to one another peculiarly interesting. On the one hand, the Nervous system renders service to the Circulatory system by its control of the movements of the heart, by means of the *vagus*, and the sympathetic nerves, and by the regulating influence which it exerts on the bore of the smaller arteries. On the other hand, the Circulatory system renders service to the Nervous system by continually supplying it with the nutriment which it needs, and apart from which all the nervous currents in it would cease to flow. Thus, as we have already seen,² each nerve, besides the nerve fibres which it contains, is

¹ See Chapter IV, p. 44.

² See Chapter XI, p. 125.

permeated by a number of minute blood-vessels—a condition of things which also prevails in both the spinal cord and in the brain. Moreover, in the brain special precautions have been taken to prevent any failure in the supply of blood to it. For this purpose no less than four distinct arteries, viz. the two *Vertebrals*¹ and the two *Internal Carotids*, enter the skull at its base, but, instead of breaking up at once into smaller vessels in the usual way, they run straight for a single circular canal,² into which they deliver their contents. Now it is from this canal, forming a kind of central reservoir, that the blood is sent out and finally distributed to the various parts of the brain. It follows, therefore, from this arrangement that, if anything should occur to block one of the four supplying arteries, the flow of blood to the cerebral hemispheres would not be seriously interfered with, as the central canal would continue to receive blood through the other three.

But if the unity which binds together the various systems in the body is one of their most striking characteristics, so also is the diversity which they display. As we pass from one to another we are continually coming upon structural devices not in the least resembling those which we have previously examined. As illustrating this, we need only compare together the lens of the eye, the valves of the heart, and the vocal cords stretched across the inside of the larynx. Or we may consider the differences which exist between the Digestive and the Respiratory systems. As they both have to do with the obtaining of life's necessary materials—food and free oxygen—we might have expected them perhaps to present a certain amount of similarity. And yet how very dissimilar they are! In the one case we have a single undivided tube of considerable length and bore which passes right through the body with an opening at both ends, whereas in the other we have a tube which almost immediately begins to break up into innumerable minute branches each terminating blindly. In the one case we have a set of auxiliary structures in the shape of glands for

¹ These are branches of the subclavian arteries (see Chapter VIII, p. 81).

² The so-called "Circle of Willis."

secreting certain juices, whereas in the other we find nothing in the least corresponding to them. And, once more, whereas in digestion all the requisite movements are made by means of muscular fibres embedded in the walls of the tube itself, in respiration they are made by one big muscle, viz. the diaphragm, assisted by certain smaller muscles attached to the ribs. And when we inquire into the reason for these differences and of several others to which I have not referred, we find that they depend on the nature of the two very different problems which had to be solved. For oxygen, being a gas and therefore extremely light, has to be taken into the body several thousands of times daily, as against the three or four times which are all that are necessary in the case of food.¹ Being a gas, too, it can be drawn rapidly through the windpipe into the lungs so as to be absorbed at once, whereas several hours have to elapse before food entering the mouth can reach the villi in the intestines. Again, oxygen does not require, like food, to be brought into any previous state of solution, neither does it require any special treatment of a chemical nature.

But the case just quoted only serves to fix attention on an important point already referred to, viz. that everywhere in the organism Life seems to have been intent on solving a number of problems, each of them more or less distinct from the rest because related in some special way to the environment. One of these problems, to give another example, was how to produce inside the body an accurate and detailed picture of the external scene. Here the laws of light had to be taken into consideration, and, to secure the desired end, a correctly shaped lens had to be provided with a screen put at exactly the right distance behind; also, a remarkable focussing arrangement was needed, and a number of other most elaborate details as described in Chapter X. When, however, the problem had to do with sound instead of light, with waves propagated through the air instead of through the ether, the ear was evolved—a receiving instrument which both in its structure and in its

¹ See Chapter VII, p. 71.

mode of action is totally unlike the eye, bearing in fact not the remotest resemblance to it.¹

Now this solving of problems, arising out of the nature of the various forces and materials existing in the environment, is one of the most distinctive characteristics of Life in all its manifold forms, whereas in the purely inorganic world we look for any such tendency in vain. How then are we going to explain this great and fundamental difference?

But to pass on. If the organs in the body have been built up into systems, and these into still higher groups, the organs themselves have been built up out of tissues, and these in their turn out of cells. Of the nature of cells and tissues I shall have more to say in the following chapter. The point, however, to which I wish to draw particular attention here is that Life not only has given rise to a number of different tissues, such as cartilage, bone, fat, muscle, nerve, etc.—a fact which in itself calls for explanation—but has utilised each of these tissues for a considerable variety of purposes in accordance with the peculiar properties of each, much in the same way as in the erection of our own buildings we utilise different materials, such as stone, brick, mortar, wood and iron.

Take for example bone. We saw in Chapter IX what a very important part it plays in connection with our movements, forming the levers to which the ends of most of our muscles are attached. But this is by no means the only purpose to which bone is applied, or those hard kinds of tissue which among the invertebrate animals take its place. The shells of molluscs and sea-urchins, for instance, are chiefly of use in affording protection; in fact, they impede movement rather than assist it. Among the higher forms, including ourselves, this protective function is well illustrated by the bones of the skull, which are so interlocked with one another along their serrated edges as to provide a rigid box for containing the soft substance of the brain. There is this further nicety about them that, hard as are both their external and internal surfaces, they contain a spongy tissue

¹ For a description of the ear I must refer the reader to one of the standard works on Physiology. See diagram, p. 222.

which serves to break the shock of any blow from outside. Similarly, the bones which build up the vertebral column give protection to the spinal cord, as it ascends to the brain in the special passage formed by them for its reception. The eyes, too, with their delicate structures are carefully lodged in the two bony cavities known as the orbits or eye-sockets, and the still more delicate structures which go to make up the internal ears are hidden away in certain curiously intricate passages scooped out in the interior of the temporal bones. Once more, the heart and the great blood-vessels immediately proceeding from it are well shielded by being placed within the arched space formed by the vertebral column, the ribs and the breast-bone.

But bones serve yet another purpose—that of support. This was scarcely needed, so long as animals did not exceed certain dimensions or lived only in the buoyant medium of water. But when they began to come out of it—for all the earliest forms of life inhabited water—and when, combined with this, they greatly increased in size, it became absolutely necessary that they should possess a strongly constructed skeleton—a rigid framework about which all their softer parts could be disposed and kept in proper position.

There are still other uses to which bones have been put. Thus the teeth and the jaws are employed in mastication, the ribs in breathing, and, in the case of birds, the hollow spaces inside the larger bones perform a respiratory function. In mammals and ourselves these same spaces are utilised as kinds of nurseries for the rearing of fresh supplies of blood corpuscles, and thus stand in intimate relation with the circulation; while in the ear the three little bones known respectively as the *Hammer*, the *Anvil* and the *Stirrup*, discharge an auditory function, since they serve to transmit the vibrations of sound from the drum to the more internal parts.

Remarks of a similar kind apply to the muscles. Muscles, as we have seen, have for their primary use to render locomotion possible, but there is scarcely a single function of the

body in the performance of which they do not assist. Thus in digestion we use the muscles of the tongue and of the throat; also the muscles, or rather the muscular fibres, which encircle the food canal and are the cause of its peristaltic movements; and, once more, the sphincter muscles which close the further outlet of the stomach and the further outlet of the intestine. Respiration, too, as already stated, is effected by the alternate contractions of certain muscles attached to the ribs, and by the contraction of that large muscular organ, the diaphragm. Again, the circulation of the blood is due to the rhythmical contraction of the muscular walls of the heart; and it is controlled also by the muscular fibres which form one of the principal coats of the arteries. Lastly, and more interesting still, we have the way in which certain muscles assist in vision. Besides the six muscles with which each eye is provided for moving it in different directions and, in the case of binocular vision, for causing the two retinal pictures to coincide, there are the muscles which open and close the lids, and inside the eyeballs there are the ciliary muscles for adjusting the focus, and the muscles for enlarging and diminishing the pupils.¹

In like manner it would not be difficult to show how each of the tissues, of which we possess so many, has been applied to quite a number of different uses. Not only in the course of Evolution have all these tissues somehow arisen, but it would appear as though some Directive influence had been steadily at work utilising each in various ways according to its inherent qualities. Whenever a particular function had to be performed, just those tissues were employed in the construction of the organ which was to perform it that were best suited to the end in view. In other words, the principle followed was, as I have said, practically identical with that which we follow ourselves, when in the construction of our houses, our pieces of furniture, our machines and other things, we use brick, stone, slate, wood, glass, iron and all sorts of other materials according to their well-known properties.

¹ See Chapter X, p. 115.

Before concluding the present chapter I should like to refer to two cases, selected out of many others, in which it would seem peculiarly difficult to account for the origin of the organs concerned on purely mechanistic principles.

The first is the remarkable arrangement with which a bee is provided for cleansing his *Antennæ*. These two horn-like appendages protruding from his head have apparently to do with both smell and hearing, and it is very important, therefore, that from time to time any particles of dust adhering to them should be removed. To accomplish this a semicircular piece has been deliberately cut out of one of the joints in each of the insect's forelegs, and the inside of the hollow curve thus produced has been bordered with a row of microscopically small teeth, forming a miniature comb almost exactly resembling one of human manufacture. When, therefore, the bee wants to clean one of his antennæ he simply bends it down and draws it from base to tip across the comb. Further, to prevent it from slipping while he is going through this operation, there is a small projecting spur which has been developed at the lower end of the joint immediately above, and with this he temporarily converts the hollowed-out curved space into a closed circular opening through which to draw his antenna.

The second case to which I wish to refer is that of the fish, *Porichthys*,¹ which lives far down in the abysmal ocean depths. As no light ever penetrates into those dim recesses, it might be supposed that eyes would be quite useless. But the *Porichthys* nevertheless possesses eyes, and, what is more, is able to see with them. This he does by means of a number of special organs known as *Photophores*, which have the singular property of emitting light. Each photophore resembles somewhat a bull's-eye lantern. Thus there is, first, a peculiar kind of tissue, which when excited becomes a source of illumination, answering to the flame inside the lantern. Behind it there is another sort of tissue, white, smooth and glistening, which acts as a reflector, while in front of it is placed a convex lens, which

¹ J. S. Kingsley's *Comparative Anatomy*, p. 23; also Dahlgren and Kepner's *Principles of Animal Histology*, p. 138.

serves to condense the rays of light and shed them out on surrounding objects. Here, then, in this animal—and there are others like it which have *independently developed similar organs*—we have the remarkable combination of an elaborate contrivance for producing light, and another equally elaborate one, viz. the eye, for receiving it, neither of which would be of the slightest use apart from the other. Consider the course taken by the emitted rays. Passing out from the body of the fish through the lenses of the photophores, they strike the surface of the sea-bottom, scattered over with its strange medley of meteoric dust, foraminiferous shells, and other organic remains. Thence the rays are dispersed in all directions through the watery medium, till some of them, which happen to be sent back in the right direction, re-enter the body of the animal through his eyes and, by means of the lenses contained in them, succeed at last in accomplishing the purpose for which all these highly complicated structures exist, viz. that of enabling the Porichthys to form a more or less accurate picture of his immediate surroundings. Otherwise there would be nothing to guide him in his search for food.

Well may we ask: By what manner of means are we to account for these most wonderful arrangements in which the end apparently sought is only gained by the co-operation of two such entirely distinct and separately evolved sets of organs as the eyes and the photophores, if all thought of any superior Guiding Intelligence is to be ruled out?

However, I do not intend at this stage to draw what to some will seem perhaps to be the only obvious conclusion. It will be better to wait till we have taken into consideration certain other matters of great importance bearing upon the subject. They are partly of an embryological character, and are partly dependent upon what we know to-day of the Evolution of Life on our little planet regarded as a whole.

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CHAPTER XIII

CELLS AND TISSUES

IN examining any complicated piece of machinery or other object, over the making of which a considerable amount of ingenuity has evidently been bestowed, we may sometimes feel curious to know how precisely it has been produced, and what have been the various stages through which it has passed on its way to completion.

A similar curiosity may well prompt us to ask : By what exact series of changes does that minute speck of living matter only $\frac{1}{250}$ th of an inch in diameter (referred to in Chapter II, paragraph 3) become transformed in the course of a few brief months into the newly-born human infant, with its highly elaborate organisation and with its several parts all working together in such perfect harmony ? How has this astounding miracle—for we can scarcely describe it otherwise—been accomplished ?

For our information on this subject we are indebted to the comparatively new science of *Embryology*, which has for its special task the tracing out of the changes in question, not only in the case of Man, but in the case of all animal and vegetable forms whatsoever. One of the most important results of these inquiries has been to establish firmly the proposition that every animal and plant, from the lowest up to the highest, starts in precisely the same way—that is, as a tiny microscopic germ-cell. It is in the germ-cell apparently that those well-nigh inscrutable forces have been hidden away which, making free use of the materials which the outer world supplies, gradually and in due course fashion forth or evolve, as we say, the adult organism.

Hence we have to distinguish between two different kinds of evolution. There is, first, the evolution of the life-

system of our planet as a whole, a process which has been going forward during the immense geological ages ; and there is, secondly, the evolution of the individual animal or plant, more frequently described as its *development*, which is accomplished in what, as compared with the other, is an exceedingly short space of time. Further, there is this difference between them, that whereas in the former case our knowledge of it is of the nature of an inference, based though it may be on an ever-accumulating number of facts,¹ in the latter case our knowledge has been acquired directly, seeing that practically every stage in the whole wonderful performance has been most carefully watched and described. Of course, this last statement is only strictly true of creatures beneath us in the scale of life, inasmuch as it is only upon them that we can freely experiment. In the case of Man certain stages only have been observed, but the gaps between them can be quite easily filled up from our knowledge of what happens in the development of those animals most nearly related to us.

The above remarks are designed to prepare the way for one of the most interesting parts of our subject, and one which, as we shall see later, opens up considerations of a most important and far-reaching kind. As, however, it would be impossible to deal with it at all adequately without some previous knowledge of the essential facts connected with cells and tissues, it is to cells and tissues that I wish to confine attention in the present chapter.

Now the fundamental thing to be borne in mind in reference to cells is that the bodies of all animals and plants are entirely constructed of them. They may be said to form the true biological units.

In the lowest forms of all—the Protozoa among animals and the Protophyta among plants—the body of each individual consists of a single cell only, but in the forms which are immediately above them it consists of a closely knit together association of cells. These associations become increasingly complex as we pass up to still higher forms, till at last, as in ourselves, millions of cells compose the

¹ See Chapter XXIV.

body, having built themselves up into the various tissues, organs, systems and groups of systems, most of which we have already described.

The term *Cell* is not altogether a happy one, and indeed is distinctly misleading. It arose in the early days of microscopical research, when chief attention was being paid to the minute structure of plants. If a thin section of any plant be examined through a fairly powerful lens, it will be seen to present a sort of honeycomb appearance. Numerous cavities will be disclosed with intervening walls which often differ from one another very considerably in size and shape and in several other ways, according to the particular part of the plant through which the thin section has been made. In the pulp of an orange, for example, the cells are spindle-shaped, thin-walled and large enough to be quite clearly made out by the naked eye. Generally, however, they are much smaller and require a good magnifying-glass. Sometimes, as in our succulent fruits, they are roughly spherical in shape, in which case we have what are known as *Intercellular Spaces*—spaces, that is, not within but *between* the cells. More often these spaces are wanting, owing to the closeness with which the cells have been pressed together, compelling them thereby to assume various forms, cubical, brick-shaped, polyhedral, etc. Of these we get good examples in the stones of plums and peaches and in the bark of trees. Again, there are cells so flattened out as to resemble the tiles of a tessellated pavement, and others so irregular in outline as to remind one of the pieces of a jigsaw puzzle. Or, once more, they may be drawn out longitudinally into prisms, cylinders and spindles; and frequently when this is the case, as in many of the tissues of the higher plants, their end partitions have been pierced with numerous holes, giving them a sieve-like appearance, or else they have been broken down altogether, so as to form long tubes or *vessels* for the readier conveyance of the sap.

Now it is not in the least surprising that with the earlier observers the appearance thus presented by the cells of being so many cavities bounded by definite walls should

have attracted chief attention, and should have led to the term "cells" being applied to them. But, as it has since been shown, it is not the cavities themselves which are of principal importance, but the wonderful little pieces of living protoplasm which they contain—protoplasm which was described by the late Professor Huxley as "the physical basis of life."

Protoplasm is composed of oxygen, hydrogen, nitrogen, carbon, sulphur and phosphorus, and of a few other elements in much smaller quantities. Its exact chemical composition is unknown. It is probably made up of a large number of different compounds all acting and reacting upon one another, as happens indeed in nearly all the processes of life. In consistency it is somewhat like jelly, and being more or less transparent, is often difficult to make out till it has been treated with some specially prepared staining solution. This is one reason, no doubt, why its great importance was for a long time overlooked. Its presence, however, may be beautifully demonstrated—without having recourse to any artificial stain—by putting under the microscope a small piece of *Epidermis* or thin skin peeled off from the under surface of a beetroot leaf, when the white walls of the cells will be seen standing out in marked contrast to their crimson-coloured protoplasmic contents. If, now, a few drops of a weak solution of common salt be added, a remarkable scene will be witnessed. In each cell the protoplasm, which has hitherto been adhering closely to the inside of the encircling wall, will suddenly shrink away and gather itself up little by little into a round, clearly defined mass in the centre. If, however, pure water be added afterwards sufficient to wash the salt away, the process will be reversed: the protoplasm will swell out again and reassume its previous shape and size.

Every plant, then, with the exception of the lowest forms, may be regarded as a vast, many-chambered structure, each chamber of which contains, or at some time or other did contain, a living inhabitant in the shape of a minute fragment of protoplasm. It is these living inhabitants which

have really constructed the walls which now shut them in; and whenever the walls are at all thick, this has been brought about by the gradual deposition of a number of successive layers upon their inner surfaces. But though each cell thus possesses a life of its own, it contributes at the same time to the larger and far more complex life of the plant as a whole. It is a member of a community of cells which by their various activities co-operate together for the good of all.

Similar remarks apply to animals, except that in their case each cell is practically naked, the surrounding wall having disappeared, or rather being represented now by a thin membrane only. Hence with animals the term "cell," though still retained, is singularly inappropriate, as it is in no sense a cavity, but simply a tiny mass of protoplasm, one of the innumerable living units which together constitute the entire organism. It is to be observed, too, that this difference as between plants and animals in the matter of a cell-wall is closely connected with their very different degrees of mobility.¹ A plant is restricted in its movements very largely because of the thickness of the walls in which its cells have encased themselves, whereas in an animal the opposite condition prevails.

Protoplasm is by no means a homogeneous substance; it exhibits a considerable amount of internal structure. Thus we may distinguish between the protoplasm of the greater portion of the cell and that of its contained *nucleus*. The latter is generally rounded or oval in shape, and, as we shall come to see by and by, is an extremely important body, exercising control over all the rest of the cell, and being the bearer in some mysterious way of the various hereditary qualities. It may be either centrally placed or in a position more or less to one side. Like the cell itself it is surrounded by a delicate membrane, but it is its internal structure which chiefly merits attention. It is traversed by a complicated network of fine, almost imperceptible threads, along which are strung in beadlike fashion a number of excessively minute granules of *Chromatin*, a substance so called

¹ See Chapter IV, p. 38.

because of the facility with which it takes up certain stains.¹

Outside the nucleus in the general substance of the cell the most important body perhaps is the *Attraction Sphere*.

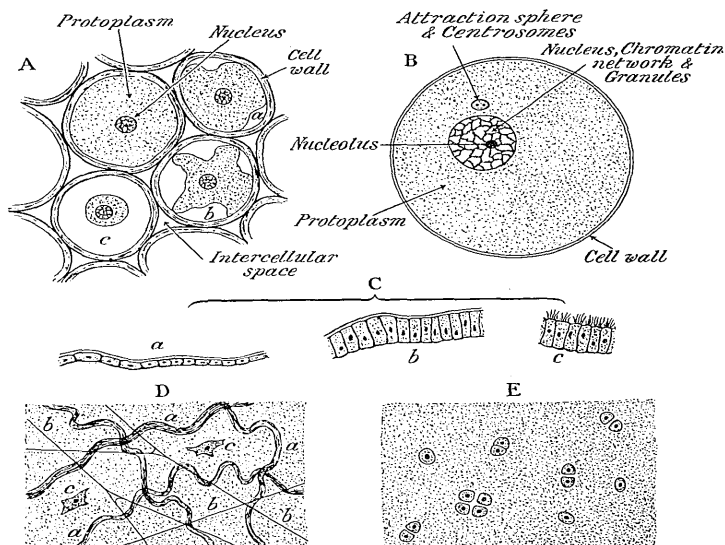


FIG. 16.—A. Vegetable Cells. *a, b, c*, Protoplasm shrinking away from walls after treatment with salt solution.

B. Diagrammatic representation of an Animal cell.

C. Epithelial Tissue. *a*, flattened cells; *b*, columnar; *c*, same provided with cilia.

D. Areolar Tissue. *a, a*, bundles of white fibres; *b, b*, yellow elastic fibres; *c, c*, cells embedded in matrix.

E. Cartilaginous Tissue. Cells embedded in matrix.

Its usual position is close to the nucleus, and in its centre may generally be recognised one or two very deeply staining particles, the so-called *Centrosomes*. Occasionally both the attraction sphere and the centrosomes are invisible—a circumstance which has led some to suppose that they have

¹ According to some the chromatin granules are not strung on the threads but embedded in them.

no continuous existence. This may be due, however, to certain temporary chemical changes which make it difficult for the eye to distinguish them from their surroundings. I may add, that scattered about in the general substance of the cell, and especially in plants, other little bodies may frequently be seen, such as the chlorophyll granules mentioned in Chapter IV as playing so important a rôle in Life's general economy; also starch-grains, crystals of various kinds, oil-drops and vacuoles, the last being clear spaces void of protoplasm and filled with a watery liquid.

The cell not only possesses structure; it is alive, and this is true of it whether it leads a separate existence as in the case of the Protozoa, or it is associated with a multitude of other cells and with them helps to build up the body of one of the higher animals. It is alive, because it is capable of taking in and assimilating food, of absorbing oxygen, of effecting a number of very important chemical changes, and in many cases of executing movements. It is also alive, because it is more or less sensitive to impressions from without, and it can grow and reproduce its own kind.

Now the *Amœba* has already furnished us (see Chapter XII) with a good example of an organism consisting of a single cell, and we have seen how it is able to perform all the above essential functions. But with certain reservations these same functions are performed by all cells whatsoever, even when, as in the human body, they are congregated together in such vast and well-nigh incalculable numbers. The fact that each contributes to the life of the entire complex organism does not interfere with the fact that each in a very true sense lives a life of its own. Each, for example, has constantly to be taking in both food and oxygen and employing them to some useful end, though it may not be obliged perhaps to go in search of them, seeing that they are continually being supplied to it free of charge, so to speak, by that great carrying agent, the blood. Of course with cells placed like these in immovable juxtaposition with one another it is impossible for them to perform any locomotory movements. Such movements have become practically restricted now to the multicellular organism as a

whole, whose business it is to make due provision for all its constituent parts wherever situated.¹

We pass on next to the Tissues. A tissue may best perhaps be defined as a number of similar or very nearly similar cells structurally united together for the performance of some definite, but comparatively quite simple, function. As there are several different kinds of cells in the animal body, and they may be united together in several different ways, it follows that a considerable variety of tissues is possible. They may be classified under four principal heads, viz. the Epithelial, the Connective; the Muscular and the Nervous Tissues.

1. The *Epithelial Tissues* are much the simplest. The cells composing them are of a primitive type, and are so joined together that no intercellular spaces are left. They are either arranged in a single layer or, as in the skin, they may be several layers deep. They line throughout their whole extent the alimentary and the respiratory passages, including the internal surfaces of all the ducts communicating with these passages. They also line the chambers of the heart, the blood-vessels, the urinary bladder, the ventricles of the brain, and the little channel running up the centre of the spinal cord, besides being found in many other localities. The individual cells may be either flat and scale-like as in the outermost layers of the skin, or columnar in shape as in the walls of the stomach and the intestines. Occasionally these columnar cells are provided on their free surfaces with a number of minute hair-like appendages known as *Cilia*, which are always more or less in a state of vibration. There are some twenty to thirty of them attached to each cell, and their lashing movements are repeated from twelve to twenty times per second.² In the respiratory passages they serve the purpose of continually pushing forward the mucus in the direction of the throat, as well as any extraneous particles which may have become entangled in it.

¹ Exceptions to this are afforded by the so-called wandering cells and by the phagocytes, which pounce upon and devour the bacteria of disease.

² Starling, *Principles of Human Physiology*, p. 248.

Closely allied to the epithelial tissues are the glandular ones. The cells composing them are joined together in more or less compact masses, as for instance in the liver, and, further, they have had the important task assigned them of manufacturing certain specific secretions out of the materials supplied to them by the blood.

II. The *Connective Tissues* form a somewhat extensive group, including the connective tissues proper and also cartilage and bone. They are distinguished by the fact that their cells, instead of being in contact with one another as in the previous group, are generally set at certain distances apart, like plums in a Christmas pudding. The spaces between them are filled with what is known as the *Matrix* or *Ground-substance*, which is really a product of the activity of the cells embedded in it. It may be regarded, therefore, as corresponding to the secretion of a set of gland cells, only in this case the secretion is of a solid kind, and there is of course no duct to carry it away. In their embryonic condition connective-tissue cells lie close to one another, but as development proceeds they separate and get pushed further and further apart by the growth and gradual accumulation of the ground-substance. Also, the ground-substance, as time goes on, often becomes changed in character, fibres of various kinds making their appearance in it; and, again, from being soft and yielding it may become tough as in cartilage, or extremely hard as in bone.

(A) Among the connective tissues proper we may reckon the four following chief varieties:—

(a) *Areolar Tissue*, so called because its ground-substance is not absolutely continuous, but abounds in open spaces which communicate with one another and may sometimes become inflated with liquid or even with air. Moreover, in the course of its development the ground-substance gives rise to two different kinds of fibres, the white and the yellow, which become embedded in it along with the cells. The white fibres are tough, inextensible, unbranched and are arranged in long wavy bundles, whereas the yellow fibres are elastic, much branched and not arranged in bundles. The former kind contribute to the strength of

the tissue, the latter to its yielding qualities. Areolar tissue is found nearly everywhere in the body, binding all the different parts together, and yet in such a manner as to permit of a considerable amount of movement.

(b) *White Fibrous Tissue*.—In this variety the white fibres have become multiplied to such an extent that the ground-substance appears to consist almost entirely of them. The yellow fibres are few and far between, and even the cells look as if they were no longer of any importance. This is the tissue which enters so largely into the construction of the tendons and ligaments, and to which they owe their firmness and strength.

(c) *Yellow Elastic Tissue*.—Here we have an opposite condition of things, viz. a great multiplication of elastic fibres. In the human body, however, this tissue is only found in certain special places and in comparatively small quantities, as in the larynx and in the walls of the arteries, where it fulfils a very important purpose (see the end of Chapter VIII).

(d) *Fatty Tissue*.—This may be regarded as a special modification of areolar tissue, the cells of which have accumulated in their interiors large quantities of fat. Fatty tissue may be found in almost any part of the body except the inside of the skull, and a few other places.

(B) *Cartilage*.—Cartilage, commonly spoken of as gristle, differs chiefly from other forms of connective tissue by its matrix being impregnated with *Chondrin*, a substance allied to gelatin, the effect of which is to render it tough and also to a certain extent yielding. Fibres, both white and yellow ones, often occur in it, giving rise to special varieties, but at other times the matrix appears homogeneous or slightly granular. The cells embedded in it are generally arranged in little groups of two, four or eight, each being enclosed in a small capsule. Cartilage is not directly supplied with blood, but numerous minute channels have been detected permeating its substance, through which flows a clear nutrient liquid derived from the blood contained in the neighbouring vessels. This tissue is found in various parts of the body, e.g. between the vertebræ, on the articular surfaces

of bones, in the windpipe, the larynx, the nose and the external ear.

(C) *Bone*.—This is much more complicated in structure than any of the tissues hitherto described. Let us take, for example, the *Femur* or great thigh bone. With the exception of the articular surfaces at the hip and at the knee,

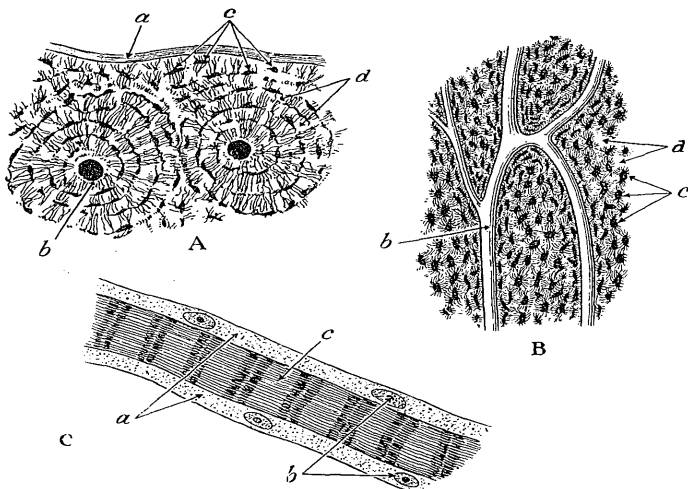


FIG. 17.—A. Cross-section of Bone. *a*, Periosteum; *b*, Haversian canal; *c*, Lacunæ enclosing bone-cells; *d*, Canaliculi.
 B. Longitudinal section of Bone; same lettering.
 C. Part of a Muscle Cell. *a*, Protoplasm; *b*, Nuclei; *c*, Fibre, showing fibrils and alternate light and dark strips.

which, as I have just said, are capped with cartilage, it is closely invested throughout its entire length with what is known as the *Periosteum*. This consists of a very tough and strong outer layer of white fibrous tissue, to which at various places the tendons of the muscles are attached, and of an inner layer containing fibres of the yellow elastic variety. The whole is permeated with minute capillaries for supplying blood to the underlying bone.

Down the centre of the bone runs a long cylindrical

cavity filled with marrow, which is a loose kind of connective tissue containing fat cells and certain other cells busily engaged in the manufacture of red-blood corpuscles.

In addition to this large central cavity the bone is traversed by a number of tubular passages, each about $\frac{1}{500}$ th of an inch in diameter, known as the *Haversian Canals*. These pursue a generally longitudinal course, but every now and again they branch and so effect junctions with one another. In cross-section each Haversian canal is seen to be surrounded by a series of curious concentric layers, the so-called *Lamellæ*, and between these lamellæ disposed at certain intervals are the *Lacunæ*, tiny spaces which communicate with one another and also with the central canal by means of numerous radially arranged very minute channels, the *Canaliculi*. The entire structure, consisting, that is, of the Haversian canal, the lamellæ, the lacunæ, and the canaliculi, forms what is known as a *Haversian System*, and it is these Haversian systems, running for the most part parallel to one another, which together make up the greater portion of the substance of the bone. The rest of it is composed of lamellæ of a similar kind filling up the triangular spaces between the Haversian systems, as also of other lamellæ on the outside of the bone just beneath the periosteum and concentric with it.

Now the whole of this somewhat intricate arrangement must be regarded as of secondary origin, seeing that, like the white and yellow fibres in the ordinary connective tissues, it has arisen by way of special development in the bone matrix. The actual bone-cells, as distinct from the matrix, are to be found inside the lacunæ, in which, however, they are not entirely imprisoned, inasmuch as they communicate with one another by means of the canaliculi. Through these, it appears, they are able to protrude in amœba-like fashion certain delicate extensions of their own protoplasmic substance, and again it is through these that they obtain their nutriment, which is derived from the minute blood-vessels coursing along the central Haversian canal.

As to the lamellæ, they have been shown under high

magnifying powers to be composed of an exceedingly fine network of interlacing fibrils, in the interstices of which phosphate of lime and other lime salts have been deposited, and it is these, of course, which give to the bone its peculiar hardness. It is, further, an interesting fact that the fibrils in any particular lamella are, for the sake of conferring additional strength, set at right angles to the fibrils of the two adjoining lamellæ, and that for the same reason there are other fibrils which cross over from one lamella to another so as to bolt them together.

In the above description the important point to be borne in mind is that all those special qualities which we generally associate with bone, and which render it of such service in the body, are dependent upon structures which have been developed in the ground-substance or matrix. Apart, however, from the activity of the bone-cells shut up now in the lacunæ and looking so inconspicuous there, these structures, as we shall see in a later chapter (Chapter XVI), would not have arisen.

It remains to add that true bone is only found among the Vertebrates. The hard parts possessed by some of the lower animals, such as the shells of molluscs and echinoderms, are of an altogether different nature.

III. *Muscular Tissue*.—All animals possess more or less the power to move, which, as we have seen (Chapter IV), is one of the chief characteristics marking them off from plants. As evolution has proceeded, this power has been greatly increased and at the same time rendered more perfect and precise. The sluggish and comparatively simple movements of the *Amœba* have been replaced by the rapid and highly complicated movements of the fish as it darts into its hiding-place, of the flying bird and of the bounding deer. This is due to the fact that certain cells have become specially modified so as to perform this particular kind of work. I refer, of course, to the muscle cells, which in their combination with one another build up muscular tissue.

In Chapter IX this subject has already been touched upon, and I have explained how a muscle, whether of the voluntary or of the involuntary kind, is composed of a

large number of more or less parallel fibres. It has now to be stated that these fibres are really cells—cells which have undergone a remarkable development in length. Thus in a voluntary muscle the length of a cell may exceed its diameter by more than five hundred times.

Further, for the proper control of these long-drawn-out cells the nucleus in each has broken itself up into a number of separate nuclei, which are scattered at intervals along its length in immediate contact with the cell-membrane, otherwise known as the *Sarcolemma*. The sarcolemma is in part formed, however, by a closely investing sheath of very much smaller connective-tissue cells.

Again, in order that it may contract swiftly, when excited by a nervous current reaching it from the spinal cord or brain, each muscle cell has developed in its interior a large number of minute threads or fibrils running parallel to one another throughout its length. These are the real contractile elements which by their sudden shortening bring about the contraction of the muscle as a whole. Each fibril is marked with a series of transverse stripes alternately light and dark, which exhibit certain curious changes of appearance whenever contraction takes place—changes which have been differently interpreted by different writers. It must be added that to perform its task a muscle has to be plentifully supplied with blood-vessels for conveying to it the oxygen and the various products of digestion which by their combination, as previously explained, are the source of its energy.

Without going any further into the subject, it is well to bear in mind that the fibres and fibrils above referred to in no sense correspond to the structures similarly named as occurring in the connective tissues. In the connective tissues they are special formations which have arisen in their ground-substance, whereas in muscular tissue no ground-substance exists, and a fibre is simply another name for a muscle cell, in the interior of which those characteristic and most important little bodies, the contractile fibrils, have originated.

IV. *Nervous Tissue*.—Not much need be said under this

head as the subject has already been dealt with in Chapter XI. It was there explained that the nervous system consists of a vast assemblage of nerve cells, otherwise known as neurones. Their special function is to convey nervous currents with rapidity from the organs of sense and other parts up to the spinal cord and the brain, and afterwards to return them, but by different routes, to the muscles, the glands and the organs of movement. It was also explained that in the passage of these currents through certain regions of the brain—the cortex of the two cerebral hemispheres—consciousness is aroused, and that consciousness, so we seem compelled to believe, exercises some very important controlling influence on the direction which the currents take.

That the neurones may be able to transmit these currents, their development differs in one important respect from that of all other cells. They put forth from their own substance a number of extraordinary processes known as dendrons, axons, collaterals, etc., which in the interior of the brain and the spinal cord form a highly complicated network, but which passing out into the other parts of the body become the fibres, or rather the axis-cylinders, of the fibres constituting the nerves. A nerve is composed, so we saw, of a number of these fibres all running parallel to one another and bound together by connective tissue, and it is along their contained axis-cylinders, often several inches and even feet in length, that the nervous currents are conveyed. It must clearly, therefore, be understood that axis-cylinders are really prolongations of the nervous substance belonging to certain cells situated either in the brain, in the spinal cord or in the ganglia. Thus they form a system of swift telegraphic communication between all the different parts of the body.

In the above brief description of the principal animal tissues I have had three objects in view. First, to emphasise and give greater precision to the general statement, that the body is entirely built up of cells and of such substances as from time to time are the result of their activity. Secondly, to illustrate still further the principle on which I have

already dwelt so largely, viz. the wonderful purposiveness of all organic structures down even to the most minute. And thirdly, to enable us to realise more fully the tremendous nature of the problem with which we are confronted, whenever we think on the one hand of the well-nigh infinite complexity of parts which distinguishes the adult individual, and on the other of the apparent extreme simplicity of the tiny germ-cell from which the adult individual is gradually developed.

CHAPTER XIV

THE DEVELOPMENT OF THE INDIVIDUAL

IN this and the two following chapters I shall try to indicate in as succinct a manner as possible the general character of that marvellous process by which the original germ-cell, so small and apparently so simple, is gradually transformed into the complex, fully grown adult individual.

Not only is the subject in itself extremely interesting, but it is of quite exceptional importance in view of its bearing on certain conclusions to which I hope to draw attention by and by. Hence the need for coming to some sort of a clear understanding of the essential points in connection with it, though necessarily, when dealing in a work like this with so vast a theme, a large amount of detail must be passed over altogether.

It does not require much reflection to see that for such a transformation to take place, as the one which we have now to consider, a great number of changes must be involved. First, there is the enormous increase in size of the developing organism. It has been roughly computed that the average new-born child exceeds in volume the germ-cell which has given rise to it by some seven hundred million times. Secondly, there is the change brought about in the external configuration of the body. To begin with, we have simply a round, but otherwise quite shapeless, little piece of protoplasm; it is only as time goes on that there gradually appears that division into head and trunk, upper and lower limbs, fingers and toes, etc., with which we are so familiar. Thirdly, accompanying these changes it is obvious from what was said in the preceding chapter that there must be an enormous multiplication of the individual cells. The germ-cell is one cell only, whereas

the body, as development proceeds, comes to consist of many millions of them. Fourthly, side by side with this multiplying process, the cells are continually undergoing changes of a profound qualitative kind, by which they are converted, as the case may be, into epithelial, glandular or connective tissue, into cartilage, bone, muscle or nerve—a process generally described as *differentiation*. Fifthly, these changes take place, not anyhow, but in accordance with a definite prearranged plan, which so orders it that the different kinds of cells, and of the tissues and organs compounded of them, shall make their appearance in the body just in their right places, and that each of them shall be of its proper shape and size. Sixthly, following upon these changes, the organism when fully grown must itself be the seat of changes, no idly standing machine, but one incessantly at work, its various parts all duly and efficiently performing their specially assigned tasks. And lastly, when the adult stage is reached, it must resemble in all essential respects, down even to some of the most minute structural details, the parent organism or organisms from which it has been derived.

As to the origin of the germ-cell I need only say here, that it is generally formed by the union of two previously existing cells, one of which, the *Spermatozoon*, is supplied by the male parent, whilst the other, the *Ovum* or egg-cell, is supplied by the female parent.¹ This union, otherwise termed *Fertilisation*, having been effected development immediately begins.

The first sign that it has really begun is shown by the nucleus, which is soon seen to be dividing. Presently its two halves draw asunder, and in the space between them, and at right angles to the line joining them, a thin partition forms, which shortly afterwards extends across the entire cell, dividing it into two. Thus two cells in close juxtaposition with one another have come to take the place of one, each having its own nucleus and its own share of the original surrounding protoplasm.

Now in the case of unicellular organisms like the Protozoa,

¹ Practically the same thing happens in plants.

what usually happens next is that the two cells separate and begin to lead independent lives. The mother-cell disappears, so to speak, and a couple of daughter-cells take its place. Further, by a repetition of the same process these two new cells soon become four, and the four eight, and so on, till at last we get a perfect shoal of minute organisms, each of which is descended, of course, from the single original cell. Reproduction, therefore, as it occurs among these lowliest of living forms, could scarcely be more simply accomplished.¹

In all the higher forms, ourselves included, the course pursued is very different. The germ-cell divides into two, but the two cleave together, they do not separate; and though division follows fast upon division and by and by there may be an enormous multitude of these cells all tracing their descent back to the solitary germ-cell, they still remain in living union with one another and continue to grow and multiply, till finally all the many millions have been produced which are needed for the construction of the fully developed multicellular organism.

From this it follows that no cell ever arises spontaneously, but always in consequence of the division of some previously existing cell.² The same holds good of those special cells, the spermatozoa and ova, which are concerned in reproduction and which are invariably derived from certain other cells situated in the bodies of the male and female parents respectively. In fact, extending our view to the life-system of our world as a whole, we may say—assuming that the doctrine of common descent is true—that all cells wherever found stand in genealogical relation to one another.

I have referred to the division of a cell, as though it were a comparatively simple process. This, however, is very far from being the case. Indeed, it is doubtful whether in the whole realm of biological discovery there is anything which can quite compare with the extraordinary character

¹ Of course I do not mean it to be inferred from this that there are not more elaborate methods by which at times the Protozoa reproduce themselves.

² But see Chapter XXIX, pp. 434, 435.

of the details which I have now to describe, and with the extraordinary interest which attaches to their possible interpretation.

Now it will be remembered (see the previous chapter) that the nucleus in every cell is surrounded by a delicate mem-

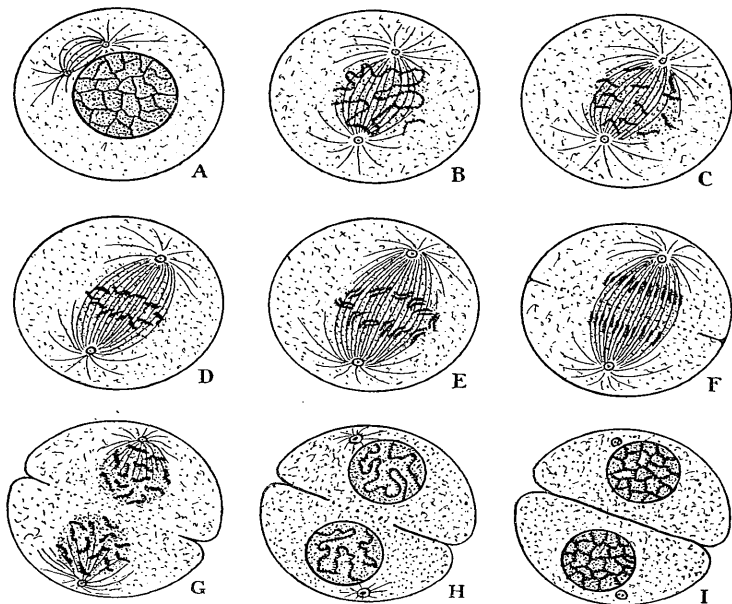


FIG. 18.—Cell Division, highly diagrammatic. A—I, the successive stages. For explanation see text.

brane, and that its interior is traversed by a remarkable network of threads on which are arranged, looking like so many beads, a large number of so-called chromatin granules. It will also be remembered that outside the nucleus, and usually in close proximity to it, we find—embedded, that is, in the general substance of the protoplasm—what is known as the attraction sphere, and that inside this there are usually to be seen a pair of extremely minute particles,

the centrosomes. Now the fact that there are two of them in place of the one which was originally there and which divided only a short time previously, indicates that the cell itself is getting ready for its next division. When, therefore, the right moment arrives the two centrosomes begin to recede from one another, and as they do so there gradually comes into view, encircling each of them, a system of very fine radiating filaments which are shot out in every direction through the surrounding protoplasm. Not all of them, however, run straight outwards. Some following paths more or less curved serve to join up the centrosomes with one another, so as to form what is known as the *Achromatic Spindle*. This in its general appearance bears a striking resemblance to the figure produced by scattering iron filings on a sheet of paper, beneath which a small bar magnet has been placed.¹

Next, the centrosomes, continuing to move apart from each other, take up positions on opposite sides of the nucleus, and the nuclear membrane somehow disappearing, the spindle filaments are enabled thereby to penetrate into the space hitherto enclosed by it.

Meanwhile changes of a very important kind have been going forward in the nuclear substance itself. The chromatin network has gathered itself up into a single much convoluted thread—the so-called *Spireme*—on which the chromatin granules are still arranged in serial order. This thread divides itself next into a number of separate pieces of approximately equal length, just as though it had been cut across at several points by some sharp instrument. Now these separate pieces are known as *Chromosomes*, and as they will play a very prominent part in some of the discussions which are to follow, it will be well to bear the term in mind. By shortening in length and at the same time growing thicker, the chromosomes gradually assume a rodlike appearance, often becoming bent upon themselves into shapes resembling j's, u's and v's. Then, as if under the control of some unseen magician, they arrange themselves in a flat disc or ring and proceed to take up an

¹ Hartog, *Problems of Life and Reproduction*, pp. 92-139.

equatorial position inside the spindle—that is, in a plane perpendicular to its axis and midway between the two centrosomes forming its extremities. Here they enter into some kind of mysterious relation with the spindle filaments, becoming apparently attached to them, until presently each is seen to have split itself *longitudinally* into two equal halves, with the result that the total number of the chromosomes is now doubled. In this process not only has each chromosome undergone division, but the same has happened in the case of each of the chromatin granules composing it. Sometimes, indeed, the latter divide at a still earlier stage—previous, that is, to the breaking up of the continuous spireme thread. But however that may be, no sooner have the chromosomes doubled their number than they begin to draw asunder, half of them travelling along the spindle threads in the direction of one of the centrosomes, and half of them in the direction of the other, thereby forming two groups. Further—and this is a very important point—if we denote the original chromosomes in the mother-nucleus by the symbols A, B, C, D, etc., and the new chromosomes which are the result of their splitting by the pairs A, A; B, B; C, C; D, D, etc., then each of the two groups just mentioned receives an A, a B, a C, a D, etc., and is consequently, so far as one can judge, of exactly the same constitution as the group within the mother-nucleus from which it has been derived. What happens may be diagrammatically represented thus :

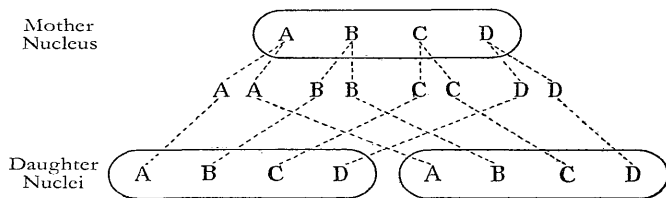


FIG. 19.

Next, the chromosomes belonging to each group, having moved still farther away from the equatorial position, begin

to join together so as to form once more a continuous thread, which soon transforms itself into a chromatin network and becomes surrounded with a nuclear membrane. Thus two nuclei, apparently constituted just like the original one, have now taken its place, and outside each of them a centrosome may be seen which already in many cases appears double, as if getting ready for the following division. As for the achromatic spindle, it soon fades away, having done its work, and the whole process is completed by the formation in the equatorial plane of a partition which divides the protoplasmic substance surrounding the nuclei, and therefore the cell itself, into two more or less equal portions. After this the two new cells remain for a longer or shorter time in what is somewhat inappropriately known as the *resting-stage*, at the end of which they begin, as a rule, to divide again.

Now it seems almost impossible to follow out in detail this extraordinarily elaborate, this amazing piece of business, without inquiring as to its *raison d'être*. Our curiosity, too, is all the more excited by it, when we remember that it is repeated every time a cell divides,¹ and that it must, therefore, occur millions of times over during the embryonic development, for instance, of every human being.

Relegating much that has to be said on this subject to future chapters, there are certain facts and inferences flowing from them which may as well be stated now. I will number them as I proceed.

1. First, there is good reason to believe that the chromosomes, which only appear as so many distinct bodies when a cell is in the act of dividing, are identical with those which joined together to form the nuclear network at the end of the previous cell-division. They may have increased in size during the interval, as is the way more or less with all living structures, but they have nevertheless retained their individuality. In proof of this the two following facts may be noted :—

¹ There are certain exceptions to this, but we need not trouble about them here.

(a) The number of the chromosomes always remains constant. For instance, if at the end of a particular cell-division twelve chromosomes join together to form the nuclear network, then the latter at the next cell-division will break up into twelve again. And it will happen similarly whatever the original number may have been.

(b) Although in the majority of cases there are, as seen under the microscope, no *recognisable* differences between the chromosomes in a given cell as regards either their shape or their size, there are a few notable exceptions to this rule. Thus in the fruit-fly, *Drosophila ampelophila*, each of the cells of which contains eight chromosomes, two of them are always considerably smaller than the others, and among the latter there are, again, certain slight differences in shape and size. Seeing, now, that at each fresh cell-division all these peculiarities reappear, we seem to have proof positive that in the fruit-fly at all events the chromosomes pass through the resting-stage without losing their identity. But if this be so in a case in which it happens that the microscope clearly reveals the existence of such differences, there is good reason for thinking it to be true in all other cases.

2. Secondly, in any individual organism, whether animal or vegetable, the number of the chromosomes is invariably the same in *all* the cells of its body, no matter of what particular kind the cells may be, or however many times, reckoning from the original germ-cell, division may have taken place.¹ This indeed follows from what has just been said under (a).

3. Thirdly, the number of the chromosomes is the same for all individuals belonging to the same species, although the number varies as we pass from one species to another. In some of the sharks, for instance, it is 36; in the earth-worm it is 32; in the snail, the trout, the frog and the mouse, as also in the lily and the monkshood, it is 24; in the sea-urchin it is 18; in the slug, the guinea-pig, the rat and the ox, as also in wheat and in several other plants, it

¹ There is a very important exception to this in the case of the reproductive cells, the ova and spermatozoa. See pp. 231-238.

is 16; in the grasshopper it is 12; and it is 8, 4 and 2 in different kinds of worms.¹

4. Fourthly, as is shown in the above list, the number of the chromosomes is in nearly every case an even one, although curiously enough in certain species the number is an even one only in the females, and an odd one—always just one less—in the males. Thus in a woman the number is stated by some to be 48, whereas in a man it is 47. But to this, as to many other facts of a like extraordinary character, I shall have to return later on (Chapter XVII).

5. Fifthly, there is reason to believe that the chromosomes within the nucleus are all *qualitatively* different from one another—that is, in their inner constitution, although it may be impossible through the microscope to detect any indications of this. On any other supposition it is exceedingly difficult to explain why, at every cell-division, each chromosome should split itself longitudinally into exactly equal halves, and why such evident pains should be taken to pass on these halves without fail—one to each of the two resulting daughter-cells. For if the chromosomes were qualitatively all alike and could be represented, therefore, by a number of identical letters, as, for example, by A, A, A, A, etc., instead of by the letters A, B, C, D, etc., the process of division, as it actually occurs, would seem quite unnecessarily complicated.

A simple illustration will perhaps make this clear. Suppose there were six equally good apples to be equally divided between two children. Obviously it could be done at once by giving three to each child, nor would it make the least difference which three out of the six each child received. Or the apples might be put into a bag and the children told to draw them out in turns. If, however, instead of six apples there was an assortment consisting of an apple, a pear, an orange, a lemon, a plum and a peach, there would be no other way of apportioning them equally, except by cutting each in half and giving a half of each to each child.

¹ E. B. Wilson, *The Cell in Development and Inheritance*, p. 206; but some of the numbers are given differently by T. H. Morgan in *Mechanism of Mendelian Heredity*, p. 26.

Nor would it do having cut them in halves to put them into a bag and tell the children to draw as before, thus leaving the thing to chance, as obviously there would be nothing to prevent the same child from drawing both halves, say, of the apple or the peach.

To apply the illustration, the very fact that so much pains has been taken to secure the division of the chromosomes into equal and similar halves, and to see that these halves are distributed afterwards in the manner described, seems strongly to suggest, though not absolutely to prove, that the chromosomes, even when they appear precisely alike, are nevertheless qualitatively different, and that some very important end is subserved by what occurs.

6. Sixthly, what has just been said applies equally to the chromatin granules, each of which divides when the chromosome containing them divides. We must, therefore, regard them also as being in all probability qualitatively different.

7. Lastly, if the above conclusions are correct, it follows that in every cell in the body not only is the *number* of the chromosomes always the same,¹ but the *qualitative differences* distinguishing them from one another are the same, and are, moreover, the same as those which characterised the chromosomes in the original germ-cell. But this, as we shall see later on, was called in question by Weismann.

To pass on. For the development of any one of the higher organisms from the fertilised egg-cell onwards, much else is required besides the wonderful and continually repeated act of cell-division above described. As stated at the beginning of this chapter, the cells must not only multiply; they must take on all those distinctive characters which are needed, if they are to form cartilage, bone, muscle, nerve and so forth. And these tissues must not make their appearance anyhow, but always in such a way as to build up properly the various organs—the stomach, the heart, the brain, etc.—each of which must be of the right shape and size and internal construction, and must occupy its right position in relation to the rest of the body. That all this

¹ Again with the exception of the reproductive cells,

should somehow be accomplished, and, in the case of a human being, accomplished during the brief space of nine months, is not only an indisputable fact, but one which, the longer we reflect upon it, fills the mind with astonishment, however we may try to account for it. But leaving for the present all such attempts on one side, it will be well to fix attention on the fact itself and endeavour to gain some slight acquaintance with the general course of events by which the transformation is effected.

For the main purpose, however, which I have in view it will not be necessary to do more than give a brief outline of what takes place in the *earlier stages* of the development, during which time the alimentary canal, the vertebral column, the brain and the spinal cord, the eye and the ear, the heart and the great blood-vessels, all make their appearance. On each of these something will have to be said in the following chapters, as also on a few other matters of quite peculiar interest, such as the means which are employed, first in birds and then in mammals, for supplying the growing embryo with its needful food and oxygen.

Again, to prepare the way for what is to follow and so make the whole subject as clear as possible, I propose in the remainder of this chapter to describe what happens in the case of a few typical organisms very low down in the scale of life—organisms but slightly removed from those which, like the amœba, consist of a single cell only.

I. First, we will take *Pandorina*, in which the course of development is extremely simple. Here the germ-cell divides and goes on dividing till the number of the cells is brought up to sixteen. These by their adhesion to one another form a solid spherical mass which is enclosed in a common membrane. Each cell being pressed upon by its neighbours becomes wedge-like in shape, with its pointed end directed inwards towards the centre. Now such an arrangement of cells is generally described as a *Morula*, because of its resemblance to a mulberry, and, as we shall see later, every organism, however high up it may be, always passes through a stage of this kind, or at least

one corresponding to it. In *Pandorina* itself each cell in addition to its nucleus possesses a contractile vesicle, *i.e.* a little hollow space filled with a watery liquid and periodi-

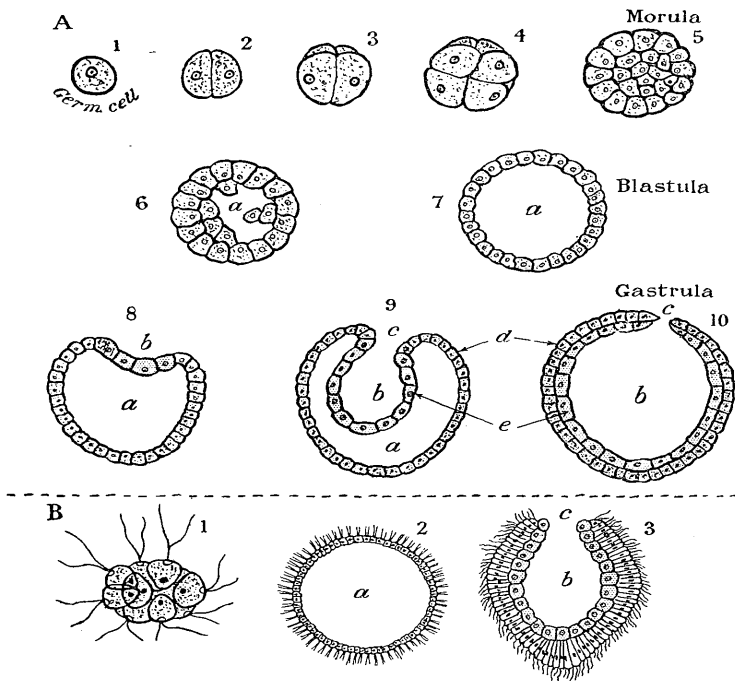


FIG. 20.—A. Illustrating Development of Germ-cell through the Morula and Blastula stages to the Gastrula stage. *a*, Segmentation Cavity; *b*, Primitive Stomach or Archenteron; *c*, Primitive Mouth; *d*, Ectoderm; *e*, Endoderm.

B. 1, *Pandorina*; 2, *Volvox*; 3, *Monoxenia*, answering to the above stages, 5, 7 and 10.

All shown in section except 1, 2, 3, 4 and *Pandorina*.

cally emptying itself of its contents. It is supposed to be performing thereby some excretory function. Moreover, each cell displays a minute red spot, thought by some to be a rudimentary eye, and it is provided with a pair of

flagella or whip-like organs which, acting in concert with those belonging to the other cells, enable the organism as a whole to move about.

II. In the development of *Volvox*¹ a still further step is taken. The process of division or *segmentation*, as it is called, gives rise first of all to a morula, but the cells instead of remaining at sixteen continue to multiply till their number reaches several hundreds and even thousands. Again, though the entire collection preserves to the end its spherical shape, it soon ceases to be a solid mass of cells. A hollow space is developed inside it known as the *Segmentation Cavity*, which goes on increasing in size till the little organism becomes a sort of bladder with a skin or wall composed of a vast number of cells exactly fitting into one another along their edges—a wall, however, which is not more than one cell thick. Thus the morula has become transformed into what is known as a *Blastula*, a stage beyond which the *Volvox* does not go. Further, if we omit certain cells specially set apart for reproductive purposes, all the other cells are, as in *Pandorina*, exactly alike—that is, they do not undergo any differentiation. Again, as in *Pandorina*, each cell possesses, besides its nucleus, a contractile vesicle, a rudimentary eye-spot and a pair of flagella. Provided with these last, it is incessantly rolling about in the water like a little fairy ball, and presenting a most beautiful appearance under the microscope.

III. For our next example we will take *Monoxenia*, a species of coral, the development of which has been described by Haeckel in his *Evolution of Man*, vol. i, p. 60. Here the embryo, after passing successively through the morula and the blastula stages, becomes what is termed a *Gastrula*, a form of very great importance, as it marks an entirely fresh step forward in the evolution of animal life. Moreover, all the higher animals, it would appear, pass through this stage, or at least through a stage very closely corresponding to it.

Now in the case of *Pandorina* and *Volvox*, as with many of the unicellular organisms immediately beneath them,

¹ See also the beginning of Chapter IV, fig. 4, p. 41.

there has been much uncertainty as to whether they should be classed as animals or plants, seeing that they partake more or less of the nature of both (see Chapter IV). With Monoxenia, however, there can be no kind of doubt, as it has developed that most characteristic of all animal organs, viz. a stomach with its accompanying mouth. Hence the use of the term *gastrula* or *stomach-animal*. As to why among animals a stomach should be considered so characteristic an organ, I will refer the reader to what has been said on this subject in Chapters IV and VI.

How, then, is this stomach formed? It might be supposed by the simple expedient of piercing a hole in the wall of the blastula, and thus converting into a stomach the enclosed segmentation cavity, when the hole leading into it would, of course, become the mouth. But this is not the plan actually adopted.

What happens instead is this. The blastula over a certain extent of its surface first flattens out and then folds inwards, forming a kind of cup, behaving much in the same way as would a hollow india-rubber ball, if pressed in on one side. The chief difference is that in the developing embryo the rim of the cup gradually closes in, till only a small aperture is left, which becomes the *Primitive Mouth*. Meanwhile, as the result of the *Invagination*—that is, of the folding in—the segmentation cavity is little by little reduced in size till it is quite obliterated, and the new cavity which has thus been formed, and into which the primitive mouth now opens, becomes the *Archenteron* or *Primitive Stomach*. It is called the *primitive* stomach because, as will be explained in the next chapter, it is only the middle portion of it which in the higher animals persists as the *permanent* stomach, while its two end portions are transformed, one into the pharynx and the gullet, and the other into the greater part of the intestine. The *primitive* mouth is so called because in the higher animals and in man it disappears altogether, a new mouth making its appearance elsewhere.

Accompanying the changes just described other changes have been going forward in the cells themselves. But first, it is obvious from its mode of formation that the archenteron

must be possessed of two coats, an inner and an outer, each consisting of a layer of cells. The cells composing the inner layer are those which were folded inwards, whereas the cells composing the outer one are those which are still occupying their former position. Now these two layers, known respectively as the *Endoderm* and the *Ectoderm*, have already in *Monoxenia* begun to take on different characters and to discharge different functions. Thus the ectodermic cells are smaller and more transparent than the others, and they have developed cilia on their outer surfaces, by means of which the little creature is able to swim about. The endodermic cells, on the other hand, are larger and more opaque, and have had the duty assigned them of carrying on the work of digestion. This they do by pouring into the internal cavity a secretion which dissolves the particles of food taken in at the mouth, and by afterwards absorbing the nutriment so obtained and allowing a certain portion of it to filter through into the cells of the ectoderm. Here, then, we clearly have a case of division of labour following upon differentiation of structure. Moreover, it is interesting to note, in connection with these two primitive layers, that whereas the endodermic cells are concerned with that very important function, the maintenance of the organism, the ectodermic cells are concerned with that equally important function, its interaction with the environment. But this is precisely the distinction on which I dwell so fully in Chapters VI to XI, and especially at the beginning of Chapter VI, when enumerating the various functions of the human body and showing how they might all be classified under a few main heads. It would appear, therefore, that even in an animal so low down comparatively in the scale of life as *Monoxenia*, this fundamental distinction has already arisen. I may add, as we shall see hereafter, that in the case of the Chordates, not only are the outer portions of the skin derived from the ectoderm, but so also are all the neurones or cells entering into the construction of the nervous system. The lens of the eye, too, together with the retina and all the more important parts of the organ of hearing, have the same origin—a most interesting fact,

because along with the nervous system each has to do with the interaction of the organism with its environment.

In a great number of instances, if not in all, the differentiation between the two aforesaid layers begins to manifest itself among the cells a considerable time before the gastrula stage is reached. The germ-cell by its first division, which, as a rule, is a vertical one, gives rise to two daughter-cells of equal size. By its second division, which is also vertical, it gives rise to four daughter-cells, which again are of equal size. By its third division, however, which is usually a horizontal one, it gives rise to eight daughter-cells, four of which are somewhat larger than the others and are more opaque. It is these four larger cells which by their multiplication and subsequent infolding lead to the formation of the endoderm, whereas the four smaller cells lead to the formation of the ectoderm. Thus at an exceedingly early stage we often find the cells getting ready, so to speak, for the two very different classes of work which they will afterwards have to perform.

Another point. It will be observed that by the process of infolding or invagination certain cells are brought into juxtaposition with one another which to begin with were far apart. I refer, of course, to the cells of the two layers forming the wall of the primitive stomach at that part of it which is opposite the primitive mouth. This affords, however, only one illustration out of countless others of the way in which during the development of the individual the cells, and sometimes whole masses of cells, shift their positions with respect to one another, in order to assist in the formation of special structures.

Lastly, the device which Nature millions of years ago hit upon—shall we say?—for producing the primitive stomach, is one to which she has repeatedly had recourse in the evolution of nearly all her higher animal forms. Invagination having once been employed, there was apparently no end to the different ways in which it could afterwards be turned to account. Thus in the human body it is surprising how large a number of organs exist for the fashioning of which this device has been resorted to,

as for example the eye, the ear, the mouth, the nostrils and the entire length of the food canal, including its various glands. To this list must be added the lungs with their many millions of minute air-cavities, and last, but not least, the nervous system. But on each of these topics there is much which I shall have to say in the two following chapters.

CHAPTER XV

THE DEVELOPMENT OF THE INDIVIDUAL

(continued)

WE will take for our next example the *Amphioxus* or *Lancelet*, a little fishlike animal about one and a half inches long, which is found in shallow seas in nearly every part of the world. Though it is much lower down in the scale of life than any of the true fishes, occupying a position almost at the bottom of the great Chordate group,¹ some knowledge of the earlier stages of its development will greatly help towards the understanding of what occurs in the case of Man as of all the other Chordates.

Starting as a single cell which, let us bear in mind, has been fertilised outside the body of the maternal organism, it rapidly undergoes a series of divisions, and in the course of about four hours becomes a blastula. Two hours later, as the result of an invagination similar to the one described in the last chapter, it reaches the gastrula stage. It is thus provided with both a primitive stomach and a primitive mouth, and its cells have already become differentiated into an ectoderm and an endoderm. In this condition it swims about freely in the water by means of its cilia, and feeds upon any particles of food which from time to time may come within its reach. It differs, however, in shape from such an organism as *Monoxenia*, in that its body has become elongated horizontally. It presents also an anterior and a posterior end, corresponding to what will ultimately become its head and its tail. A distinction, too, has arisen between its dorsal or upper surface and its ventral or lower surface,² the latter being the more rounded of the two, while the

¹ See Note at the end of Chapter II, p. 24.

² For explanation of these terms see Chapter IV.

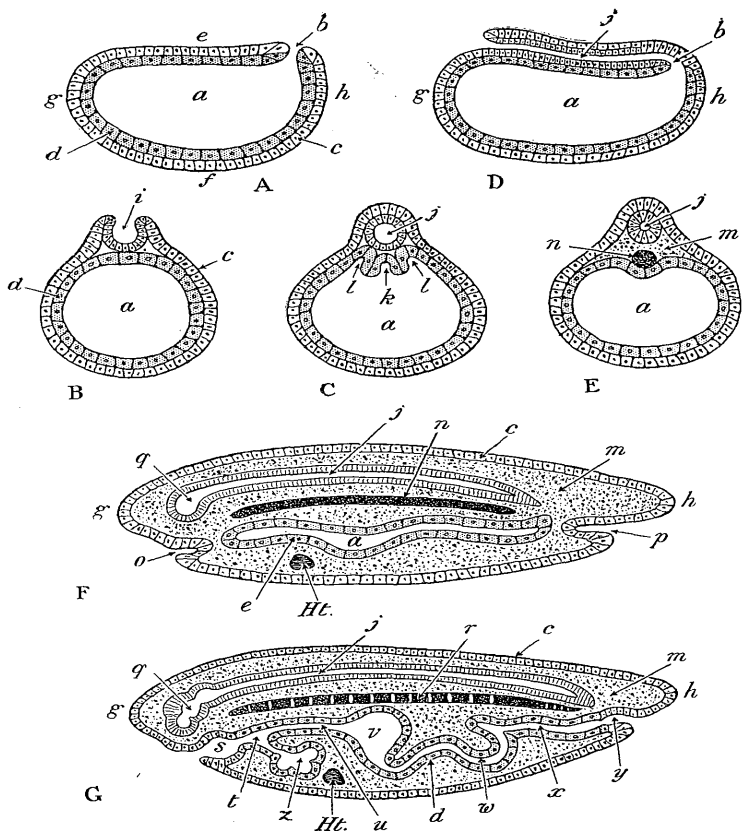


FIG. 21.—DIAGRAM ILLUSTRATING SOME OF THE EARLY STAGES IN THE DEVELOPMENT OF A CHORDATE.

A corresponds to A, 10, in fig. 20. B. A cross-section after formation of Neural groove. C. A cross-section after formation of Neural tube and of three further grooves. D. Longitudinal section of same, showing neural tube open at one end and communicating with archenteron at the other. In E, the middle groove of the three has become the Notochord, and the two lateral ones have given rise to the Mesoderm (dotted portion). F. Neural tube, now closed at both ends. In G, Brain clearly distinguishable and beginning to show division into three parts; notochord replaced by Vertebral column: archenteron differentiated into pharynx, gullet, stomach (permanent) and small and large intestines. Lungs beginning to form.

a, Archenteron; *b*, Primitive mouth; *c*, Ectoderm; *d*, Endoderm; *e*, *f*, Dorsal and ventral surfaces; *g*, *h*, Anterior and posterior ends; *i*, Neural groove; *j*, Neural tube; *k*, Middle longitudinal groove, giving rise to notochord; *l*, *l*, Lateral grooves, giving rise (in *Amphioxus*) to the mesoderm; *m*, Mesoderm; *n*, Notochord; *o*, *p*, Invaginations to form permanent mouth and anus; *q*, Brain; *r*, Vertebral column; *s*, Mouth cavity; *t*, Pharynx; *u*, Gullet; *v*, Stomach; *w*, *x*, Small and large intestines; *y*, Rectum; *z*, Lung; *Ht.*, Heart.

primitive mouth has so far shifted its position as to be situated very nearly at the posterior or tail end of the animal's body on its dorsal side. In this way the little creature has acquired a *bilaterally symmetrical* shape, and can only be divided, therefore, into two exactly similar halves—a right and a left—by a vertical plane passing from before backwards. Such a plane is generally known as the *Sagittal Plane*.

If we view it now from above—that is, on its dorsal aspect—a longitudinal furrow very soon begins to make its appearance down the middle line, ending posteriorly a little beyond the primitive mouth. This is the so-called *Neural Groove*, and it is formed by the gradual sinking downwards of a strip of ectodermic cells—another instance of an invagination, though of a somewhat different kind from that described in the previous chapter. Meanwhile, the ectoderm on each side of the groove has risen up into two parallel ridges, which presently bend over towards each other and finally unite along the middle line. By this means the neural groove is converted into the *Neural Tube*, which is thus necessarily lined throughout with ectoderm. At first the tube is open at both ends, but it very soon closes behind, and in such a manner as to include the orifice of the primitive mouth. Thus the archenteron or primitive stomach is no longer in direct communication with the external world, but only in a roundabout way through the neural tube, which is still open at its anterior or head end. This arrangement, however, does not last long, for presently the primitive mouth closes up altogether, with the result that the archenteron becomes a long tube lined as before with endoderm, but ending blindly both before and behind. Eventually the anterior opening of the neural tube closes up also.

Now it is from the neural tube, formed in the way which I have just described, that the main axis of the nervous system is developed, and this holds true both of *Amphioxus* and of all the higher Chordates. In the latter it gives rise to both the spinal cord and the brain by the continual multiplication of its ectodermic cells, and especially of those

which were the first to sink down and form the bottom of the neural groove. This multiplication of cells is particularly active, of course, in the region of the brain. Meanwhile, as the result again of the multiplication of the cells, the interior of the neural tube gradually becomes blocked up, and yet not entirely so, for the minute canal which in ourselves, for example, is found running up the centre of the spinal cord and opening out above into the ventricles of the brain, is still there to remind us of its former tubular condition.¹ The *Amphioxus*, however, can scarcely be said to possess a brain; it is represented merely by a slight swelling at the anterior end of the nervous axis or cord.

Let us turn attention now to the archenteron. At a comparatively early stage in the development of the *Amphioxus* three longitudinal grooves all parallel to one another make their appearance along its roof. Of these the central one separates itself off as a distinct tube, which soon becomes converted into a solid rod lying lengthwise in the body, with the neural tube just above it and with the archenteron just below. This rod, stiff, and yet to a certain extent flexible, is an exceedingly important structure, and amongst animals higher than *Amphioxus* forms the foundation of the Vertebral Column or backbone. It is known as the *Chorda Dorsalis*, or more briefly the *Notochord*, and it is because of their possession of it at some time or another in the course of their development, that the Chordates have received their name. Its function is supportive. In *Amphioxus*, however, it never gives rise to any vertebral column, but remains a simple undivided rod to the end of life.

The other two longitudinal grooves, lying one on each side of the central groove, also separate themselves off from the archenteron, but the process by which they do so is too elaborate to be described here. It will be enough to state that the cells composing them become the source of what is known as the *Mesoderm*, which like the ectoderm and the endoderm constitutes one of the three so-called

¹ See Chapter XI, p. 123, and XVI, p. 217.

Primitive Germinal Layers. In *Amphioxus* the mesoderm might be supposed from its mode of formation to be only a modified portion of the endoderm—and so indeed in a sense it is—but seeing that in other animals it often originates somewhat differently, it is best to regard it as taking equal rank alongside of the other two germinal layers.

In consequence of the after growth and multiplication of the mesodermic cells, they ultimately come to fill up nearly all the internal spaces of the body, except where those structures exist which are derived from the ectoderm of the neural tube and from the endoderm of the archenteron. Continuing to differentiate, they give rise to all the various kinds of connective tissue, including, in animals higher than *Amphioxus*, both cartilage and bone. They also give rise to the heart and to the whole of the circulatory and muscular systems, as well as to the essential parts connected with the urinary and the generative organs.

The archenteron does not long remain a blind tube. It is tapped at its anterior end by an invagination of the external ectoderm so as to form the *Permanent Mouth*, and it is similarly tapped at its posterior end so as to render the through passage complete. Thus the alimentary canal, as we generally know it, comes to be established. With the exception of the cavity of the mouth and the last portion of the intestine, it is, as we have seen, lined throughout with endoderm, and in most of the higher animals gradually becomes differentiated into pharynx, gullet, stomach and small and large intestines. In *Amphioxus*, however, the process is not carried quite so far, the only distinction which arises being that between the pharynx and the intestine.

In *Amphioxus* certain remarkable changes soon begin to be observed in the region of the pharynx. A series of vertical slits, known as the *Branchial Clefts*, make their appearance on each side of the head, and thereby open up communication between the interior of the pharynx and the outer world, in addition to the communication already existing through the mouth. Moreover, they go on increasing in number till in a fully grown individual there

may be as many as three hundred of them and even more. Each cleft arises as a separate evagination¹ of the endoderm lining the pharynx, which gradually pushes itself outwards till it breaks through the external ectoderm, forming thereby

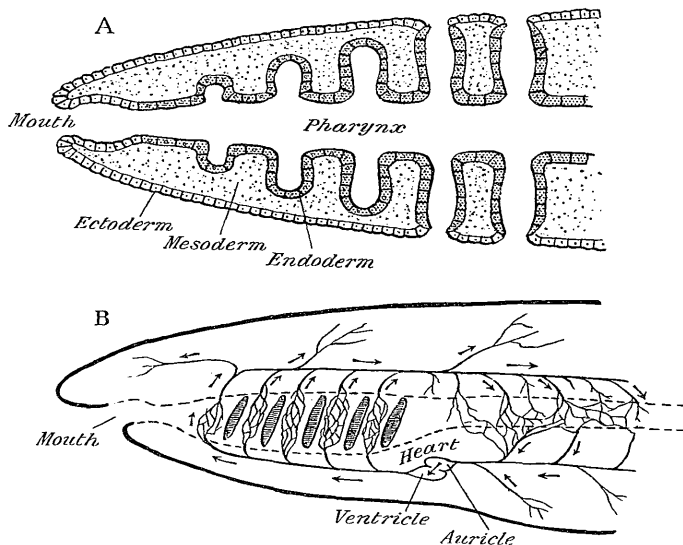


FIG. 22.—A. Horizontal section (diagrammatic), showing how the gill-slits are formed by evaginations of the endoderm lining the pharynx. In fishes these slits remain permanent. In reptiles, birds, mammals and Man they appear only for a short time.

B. Side view of Fish, showing the five gill-slits, the two-chambered heart and the general course of the circulation. Position of Food Canal indicated by dotted lines.

one of the slits. What occurs will perhaps best be understood by examining a horizontal section of the anterior end of the animal's body. As will be explained presently, the function of these branchial clefts is of a respiratory character.

Among the Chordates the circulatory system arises somewhat as follows. Certain sets of mesodermic cells arrange

¹ An outward folding as contrasted with an invagination or inward folding. But in principle the two are exactly the same.

themselves into solid strands, which bud and give off branches, and by and by unite to form a sort of network. Presently the outside cells of each strand flatten out, and by joining together along their edges produce a continuous tube.¹ Inside these tubes the other cells lose their attachment to one another and eventually become transformed into blood corpuscles. Thus in place of a network of solid strands we get a network of intercommunicating vessels full of blood. The wonderful thing is, that in an organism like our own, in which the circulatory system is so exceedingly complex, the ultimate arrangement of these blood-vessels should be of the definite kind which we actually find, and that in particular there should be no communication established between the arterial and the venous systems, except at their terminations in the capillaries, although arteries and veins are running alongside of one another into every region of the body. Of course, if any such communication on a large scale did exist, it would entirely frustrate the purpose for which the circulatory system has been evolved, for the blood would keep returning to the heart by short cuts, and so all the outlying organs and other parts would be left unvisited.

Another point. It is worth noticing that the mode of the formation of the blood-vessels is just the reverse of that employed in the formation of the organs hitherto described. The archenteron, the nerve axis and the notochord all begin as invaginations which are quickly transformed into tubes, these tubes, with the exception of the archenteron, afterwards tending to become solid structures. In the case of the blood-vessels, however, there are no invaginations; they begin as solid structures, and only subsequently become hollowed out into tubes.

In *Amphioxus* the circulatory system is much simpler than in ourselves, and it is somewhat important that it should be understood. Strictly speaking there is no heart, but as representing it there is a long contractile vessel immediately beneath the intestine, through which the blood is continually being propelled forward in the direction of

¹ Gray's *Anatomy*, 20th ed., p. 109.

the head. On reaching the pharynx this vessel gives off on each side a large number of small arteries, which make their way upwards through the partitions which separate the branchial clefts from one another.¹ The capillaries derived from these arteries deliver into a pair of parallel vessels which run backwards just above the pharynx till, close to the point where the pharynx merges into the intestine, they unite into a single longitudinal vessel immediately beneath the notochord. This vessel in its turn gives off a second set of small arteries and capillaries, which after distributing themselves in the wall of the intestine finally deliver into the long contractile vessel running forward with which we started in our description.² According to this arrangement, the blood on the ventral side of the alimentary canal is continually flowing forward, on the dorsal side it is continually flowing backward, while in order to complete the circuit it has to pass through two sets of capillaries, one in front connected with the branchial clefts, and the other behind connected with the intestine. In the former of these the blood absorbs the oxygen dissolved in the water which is taken in at the mouth, and which almost immediately streams out again through the clefts, while in the latter it absorbs the nutritious substances which have also been taken in at the mouth and have since undergone digestion.

I may remark here, that in the Fishes, which come next in order above the Amphioxus, the circulatory system is practically the same, except that the branchial clefts are very much reduced in number, and that the partitions separating them are fringed with *Branchiæ* or *Gills* for the more efficient oxygenation of the blood flowing through their capillaries. Hence the origin of the term *Branchial Clefts*. In Reptiles, Birds and Mammals, which never at any time in their lives breathe by means of gills but always by means of lungs, these branchial clefts nevertheless temporarily appear at a certain stage in their develop-

¹ It is unnecessary to enlarge here on the distinction between the primary and the secondary clefts.

² To simplify matters I have omitted all reference to the circulation in the so-called hepatic cæcum.

ment, showing along with many other indications that these higher lung-breathing animals are really descended from those which once breathed with gills. Indeed, the constant tendency of organisms to repeat in their development, though often evanescently and with considerable differences, the succession of changes which in remote geological ages their ancestors are believed to have passed through, forms one of the chief arguments in favour of the general Doctrine of Common Descent, and has been named by Haeckel the *Biogenetic Law*.¹

For the purpose which I have in view it will not be necessary to follow out any further the changes which take place in the subsequent development of Amphioxus. Enough has been said, I hope, to make clear the general nature of the process—how by the continual multiplication of the cells, by their progressive differentiations and by their invaginations, evaginations and other kindred movements, the minute solitary germ-cell is step by step transformed into the elaborately constructed organism which it finally comes to be. Further, we have seen that, low down as is the place which the Amphioxus occupies amongst the Chordates, it exhibits in those early embryonic stages, which I have endeavoured to describe, all the main features serving to mark off the Chordate group as a whole from the rest of the animal kingdom. Thus it possesses (1) a *Chorda Dorsalis*, which in the higher animals forms the foundation of the backbone; (2) a central nervous system, which is derived from a hollow tubular structure of ectodermic origin situated on the dorsal aspect of the body; and (3) a double set of branchial clefts, which have the effect of bringing into close relation with each other the digestive and the respiratory systems—a matter on which I have already enlarged at the end of Chapter IX. Moreover, each of these features appears at one time or another, whatever afterwards may become of it, in the development of all the higher forms—in Fishes, Amphibians, Reptiles, Birds and Mammals, including Man.

¹ See Chapter XXIV, pp. 368–371.

In the production, however, of most of the higher forms certain complications have been introduced which are not only extremely interesting, but have a decided bearing on my general argument. Now allusion has been made to the fact that in *Amphioxus* the ovum or egg-cell is liberated from the maternal organism previous to its fertilisation by the male element or spermatozoon. The result is, that it is only by accident, so to speak, that the ovum gets fertilised at all, and further, even when fertilisation has occurred, the chances are considerable against the little embryo ever reaching maturity, so numerous are the dangers to which it is exposed in its earlier stages. To remedy this defect, to reduce this high rate of infant mortality, the following means have been resorted to among the higher forms.

In the first place, fertilisation has been rendered far more certain by so arranging matters that the ovum and the spermatozoon shall meet one another inside the body of the female. And to secure this end that strong natural instinct has been implanted which brings the two sexes together.¹

Secondly, the young embryo, instead of being turned adrift upon the world to fend for itself as best it can in its exceedingly immature condition, is retained for a longer or shorter period inside the body of the mother, in order that it may receive from her both protection and nourishment. Among the Mammals, with the exception of the Monotremes, this period is greatly extended, so that the young are eventually brought forth alive and in a considerably advanced stage of development; whereas in the vast majority of other forms, of which Birds form a typical example, development within the mother only proceeds up to a certain point, when an egg is laid, in the interior of which the process is carried to completion. We will consider first the case of Birds and afterwards that of Mammals.

Now seeing that with the chick, for example, three weeks have to go by between the laying of the egg and the final hatching, it is plain that, shut up as it is inside the shell, it

¹ It is interesting to compare with this the way in which among most of the higher plants fertilisation by means of insects has replaced fertilisation by means of the wind.

must somehow be provided during that period with both food and oxygen, if it is to live and grow. The question is, How exactly is this effected?

So far as the food is concerned a plentiful supply of it, sufficient to last the three weeks, has already been deposited by the mother bird inside the egg previous to its being laid. Derived from the nutritious substances contained in her blood, it appears in the egg in the form of an immense number of minute rounded particles, the so-called *Yolk-granules*. Even before fertilisation has taken place, the ovum has to such an extent become laden with them, that only a small region within it has been left free. Moreover, it is in this region that the nucleus is found with its accompanying centrosomes. Because of this arrangement the process of cell-division, which begins immediately after fertilisation, pursues a somewhat different course from what it does in *Amphioxus*. It progresses rapidly enough in the neighbourhood of the nucleus, but in all other parts it is seriously impeded by the presence of the yolk-granules, which go on continually multiplying up to the time that the egg is laid.

The result is, that when the latter occurs, though the ovum has grown to an enormous size—being identical now with what we generally speak of as the yolk—it is only in one particular region of it that cell-division has actually taken place. Now this particular region corresponds to that little flat disc, the blastoderm, no bigger than the tip of one's finger, which, as stated in Chapter II, may be seen floating on the top of the yolk when an ordinary new-laid egg is opened.

Examined microscopically it is found to consist of two layers of cells, of which the upper one is the ectoderm, while from the lower one are formed, by a somewhat intricate series of changes, both the mesoderm and the endoderm. The main fact, however, to be remembered is, that at the time when the egg is laid, it is only a very limited portion of the ovum which has undergone division, the process having been stopped elsewhere by the large accumulation in it of the yolk-granules.

As for the white of the egg and the external shell, they are merely envelopes due to secretions which are poured out upon the ovum by the mother bird only a short time before the egg is laid.

No sooner, however, does the hen take to sitting on the egg, or the egg is placed inside an artificial incubator, than the process of development, which has been temporarily arrested, begins to go forward again. Thus it is not long before the neural groove is formed, followed by the neural tube, which will ultimately fashion itself into the spinal cord and the brain. About the same time the notochord appears, and presently on each side of it a longitudinal strip of mesoderm becomes cut up into a series of little cubically shaped bodies known as *Proto-vertebræ*, which in due course give rise to the true *vertebræ* as well as to a number of important muscles. Also, the minute aperture corresponding to the primitive mouth comes into view, which opens at first into the archenteron, but afterwards closes up just as in *Amphioxus*. Further, just as in *Amphioxus*, the archenteron, which at a certain stage is blind at both ends, becomes converted into a through passage by a couple of invaginations of the external ectoderm. Again, gill-slits, four in number on each side, make their appearance, though only for a time, seeing that in a bird which breathes by means of lungs there is really no need for them, and they are, therefore, to be regarded as mere vestiges, reminding us of previous ancestral conditions. Curiously enough, however, one of them on each side helps in the formation of the middle ear—the bony cavity immediately behind the drum—and this accounts for the fact that in the mature condition, both in Birds and Mammals, there is a passage, the *Eustachian Tube*, leading up to this cavity from the pharynx, a passage which often becomes inflamed or stopped up during a severe cold.

While the changes above described are in progress, others of a very different kind are taking place which are wholly unrepresented in the case of *Amphioxus*, and which issue in the formation of the three following remarkable structures, viz. the *Yolk-sac*, the *Allantois* and the *Amnion*. Each of

these, though it is only of temporary use to the growing chick and will be altogether dispensed with at the end of the three weeks of incubation, is nevertheless composed of cells derived, like those of the embryo itself, from the repeated divisions and subdivisions of the fertilised ovum.

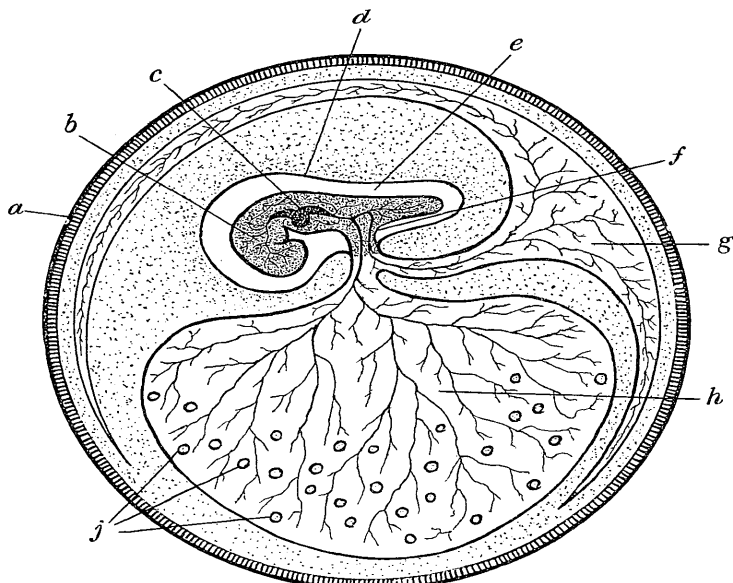


FIG. 23.—Chick Embryo and Embryonic Structures (diagrammatic). *a*, Shell; *b*, Embryo; *c*, Heart; *d*, Amnion; *e*, Amniotic cavity; *f*, Body-stalk; *g*, Allantois with ramifying vessels; *h*, Yolk-sac with ramifying vessels; *j*, Yolk-granules.

That is to say, in the Bird, as also in the Reptile and in the Mammal, not all the cells descended from the original germ-cell are employed in the building up of the organism; there are others which go to form the temporary structures just referred to, each of which has a highly important function to fulfil in relation to the growing embryo. Of the three, as found in the Bird, the Yolk-sac is concerned

with the assimilation of the food-stuffs contained in the yolk, the Allantois is concerned with the oxygenation of the blood, while the Amnion serves a purely protective purpose.

The Yolk-sac is formed as follows. While the more centrally placed cells of the blastoderm are being utilised in the construction of the body of the chick, the cells at its circumference are by their continual multiplication gradually increasing the area of the outlying portions of the disc. Thus from being of the size of a threepenny-bit, the disc grows to be of the size of a sixpence, of a shilling, of a half-crown, till at last it completely encloses the yolk in a kind of bag. This bag splits into two layers, an inner and an outer one, of which the inner one becomes the Yolk-sac. Although its cavity full of yolk is continuous with the cavity of the archenteron, being connected with it by a narrow neck or passage, it is not through this passage that the nutritious substances contained in the yolk-granules are taken in and absorbed by the embryo. They are absorbed instead by a network of minute blood-vessels spread out over the surface of the Yolk-sac—vessels which, although they are external to the embryo, are nevertheless supplied by it with blood. A pair of arteries—the *Vitelline Arteries*—convey the blood from the heart inside the embryo to this outlying sac, while a pair of veins—the *Vitelline Veins*—convey it back. Thus the growing chick is perpetually drawing on the stock of food which has been provided for it by the mother bird, and doing so by means of a peculiar extension, so to speak, of its circulatory system outside its body—an extension which, when it has done its work, is completely cast aside.

The Allantois, which is the embryonic organ of Respiration, arises as an evagination of the archenteron near its hinder end. After pushing its way out into the space left above between the chick and the shell, it applies itself closely to the internal surface of the latter, which, impervious as it may look to the naked eye, is nevertheless pierced with innumerable minute holes for the admission of the external air—surely a most marvellous provision. Consequently, if the shell is painted over with a coat of varnish or is

immersed in an atmosphere of hydrogen, the embryo very quickly dies. Moreover, that the Allantois may absorb the air, or rather the oxygen which has thus been admitted, it is provided just like the Yolk-sac with a special set of blood-vessels which are in direct communication with those inside the chick.

We see, then, that according to this twofold device, the heart, which arises at a very early stage in the course of the development,¹ not only drives the blood into every part of the growing embryo, but drives it out into both the Yolk-sac and the Allantois, in order that it may come back laden with the food and the oxygen required. And this arrangement, which is so obviously of a purposive character, appears all the more remarkable because of the fact already mentioned that it lasts only during the brief period of incubation. For when the three weeks have elapsed and the chick finally quits its shell and is no longer, therefore, in need of either Yolk-sac or Allantois, it abandons them both, and begins in the ordinary manner to take in food through its mouth and air through its nostrils, neither of which has it done before.²

As to the Amnion only a few words need be said. It is a membranous sac which completely invests the embryo, except over that small portion of its under surface which gives attachment to the body-stalk. Between it and the embryo there is a space left which is full of a watery secretion, and in this the embryo floats, though not quite freely, because held more or less in one position by the body-stalk beneath. The purpose of this arrangement is obviously to protect the embryo from anything in the nature of a sudden jar communicated to it from outside, as by a fall of the egg or by some other untoward accident. The body-stalk, it should be explained, is a kind of thick cord containing the vessels through which the blood travels outwards on its way to the Yolk-sac and to the Allantois, and afterwards returns to the embryo.

¹ During the second day of incubation.

² Strictly speaking, the breathing of air through the nostrils, and its consequent absorption by the lungs, begin a short time before the actual hatching.

When we pass up from Birds to Mammals the arrangements just described are very considerably modified. Seeing that in all except the Monotremes the development takes place entirely inside the body of the mother, there is no need for any large quantity of food to be stored up in the shape of yolk-granules, as all that is wanted can now be continuously supplied out of the mother's blood. Consequently no yolk-granules, or scarcely any, are formed, although oddly enough there is still a Yolk-sac, or rather a remnant of one, occupying the same position in relation to the embryo as in Birds and Reptiles, etc. Plainly, therefore, amongst Mammals the possession of a Yolk-sac is a kind of survival from the past, and indicates that if we could only go back far enough, we should probably find certain ancestors of theirs laying eggs full of yolk, just as Birds and Reptiles are doing to-day. Remarks of a similar kind apply to the Allantois, which also makes its appearance in connection with the Mammalian embryo, though it has long since ceased to discharge any direct respiratory function.

The extent, however, to which the Yolk-sac and the Allantois are developed—though the development is but small—varies considerably among the different mammalian orders or groups, being least perhaps in the anthropoid apes and in Man. In all the Mammals, indeed, except the Marsupials and the Monotremes, the one important organ by means of which food and oxygen are conveyed to the growing embryo is the *Placenta*. In Man the Placenta is a circular disc about seven inches in diameter and rather more than an inch thick. It is closely applied to the internal surface of the womb, and is connected with the child by means of the umbilical cord. Ramifying through its substance there are two distinct sets of vessels, in one of which the blood of the mother circulates and in the other the blood of the child. These sets are not in direct communication with each other. Nevertheless, the dissolved food-stuffs and the oxygen contained in the mother's blood are continually passing over into the blood of the child through the thin membranes or layers of cells separating the two

sets of vessels, while by a reverse process the waste products contained in the child's blood are continually passing over into the mother's blood in order to be got rid of. The child's blood is conveyed to the Placenta by the hypogastric arteries and is returned by the umbilical vein—vessels which are identical with those which once performed a like service in connection with the Allantois. Thus we see that, whereas in reptiles and birds the embryo obtains its food and its oxygen from two quite distinct sources—viz. the Yolk-sac and the Allantois—in most Mammals and in Man these are obtained from the Placenta only, both Yolk-sac and Allantois having ceased to discharge their original functions and being reduced to little more than rudimentary structures.

One portion of the Allantois, however, is retained after birth, viz. that portion of it which is inside the body of the embryo and in closest relation, therefore, with the archenteron. By a curious process it is ultimately transformed into the urinary bladder—a good illustration of the way in which it sometimes happens during development, that an organ originally intended for a certain purpose is afterwards made to subserve another which is quite different.

As for the Amnion, it persists in Mammals till the day of birth, performing exactly the same function as in Birds.

I have described at some length these truly remarkable embryonic structures—the Yolk-sac, the Allantois, the Amnion and the Placenta—because, in the first place, they afford very striking evidence in support of the doctrine of Common Descent, and because, in the second place, which is far more important, their extraordinarily purposive character would seem to defy any attempt to account for their origin along purely mechanistic lines.

CHAPTER XVI

THE DEVELOPMENT OF THE INDIVIDUAL

(continued)

I PROPOSE now to trace out a little further the development of a few of the more important organs in the body, following in the main the order in which they were described in Chapters VI to XI.

1. THE DIGESTIVE ORGANS

The digestive canal is chiefly formed, as we have already seen, out of the original archenteron, which in *Amphioxus* and in many other animals results from the invagination of certain cells belonging to the embryo when at the blastula stage, the cells in question constituting what is known as the endoderm. After the closure of the primitive mouth the archenteron becomes a tube ending blindly both before and behind ; but owing to a couple of invaginations of the external ectoderm it is soon converted into a through passage, the anterior invagination being transformed into the permanent mouth cavity. Later on in the case of Man and of most of the higher animals the whole of the middle portion of this through passage is differentiated into pharynx, gullet, stomach and small and large intestines. Further, for a considerable time it communicates ventrally with both the Yolk-sac and the Allantois, and in the region of the pharynx presents on each side a series of branchial clefts which, although they persist in Fishes, close up completely in Reptiles, Birds and Mammals.

The liver and the pancreas, those two very important glands connected with the digestive canal, are principally composed of mesoderm, but their respective ducts ¹ and

¹ The bile duct, and the duct for the discharge of the pancreatic juice.

their ramifications are, like the digestive canal itself, composed of endoderm, and are the result of evaginations of its endodermally lined walls. In other words, the cavities of these ducts and of their ramifications are not only continuous with the cavity of the digestive canal, but are produced, so to speak, by gradual extensions of it, which as development proceeds push themselves out finger-like into those surrounding masses of mesoderm which afterwards become the liver and the pancreas. As they continue to divide and subdivide, the surrounding mesoderm in the case of the liver is slowly transformed partly into those highly characteristic liver cells, the like of which are found nowhere else in the body, and partly into the arteries, veins and capillaries which have to do with the supply of the organ with blood. Meanwhile, nerves and their numerous branches have been penetrating into the substance of the liver, which nerves, be it remembered, have all ultimately been derived from that longitudinal strip of ectoderm which at a quite early stage was separated off from the rest to form the neural tube. Thus, portions of the ectoderm, the mesoderm and the endoderm have by their various very curious infoldings, outfoldings and other movements, all been brought together to assist in the construction of that highly complicated organ, the liver—a proceeding so remarkable as to raise in us once more the question as to the real nature of the cause or causes which have been at work.

The gastric glands, with their innumerable minute ducts embedded in the walls of the stomach, arise in much the same way as the liver and the pancreas, and a similar remark applies to the salivary glands, except that in their case the ducts being derived from the cavity of the mouth are lined with ectoderm instead.

2. THE RESPIRATORY ORGANS

Among the Chordates breathing is effected sometimes by means of gills and sometimes by means of lungs, according as the needful oxygen is obtained from the air dissolved

in water or from the atmosphere direct. Fishes, as also Amphibians in their tadpole condition, are provided with gills, whereas Reptiles, Birds, Mammals and Amphibians in their adult condition are provided with lungs. Gills are really outgrowths of the *Visceral Arches*, the latter term denoting those portions of the wall of the pharynx which separate the branchial clefts from one another. Into each of these visceral arches an artery runs, which, by breaking up into capillaries, supplies the gills on each side with blood, the capillaries afterwards all uniting into a vessel which conveys the blood away. Now it is while the blood is flowing through these capillaries, which are extremely thin-walled, that it absorbs the oxygen dissolved in the surrounding water. And, that the surrounding water may be continually changed, the fish is continually taking in through its mouth a fresh supply, which, after passing through the pharynx, finds its way out through the branchial clefts, bathing the external surface of the gills as it does so. Hence, if we watch a fish, we shall see that almost at every instant it is opening and shutting its mouth for this purpose, and at the same time water is escaping from behind a pair of flaps which are placed one on each side of its head. In most fishes these flaps conceal the branchial clefts and the attached gills, but in others, such as the sharks and the dog-fishes, the flaps are wanting, and so the branchial clefts are uncovered and quite conspicuous.

Lungs when present are developed like gills in close connection with the pharynx, or rather with its lower end where it passes into the gullet. A groove appears, the *Tracheal Groove*, on its internal ventral surface. This in Man becomes converted into a hollow longitudinal tube opening above into the pharynx, but ending blindly below. It is, of course, the rudiment of the windpipe, and being derived from the pharynx is consequently lined with endoderm. As it lengthens, and in so doing grows downwards, it divides into two branches, which ultimately become the right and the left bronchi, supplying air to the right and the left lungs respectively. Each of these branches, continuing to extend itself, forces its way into a mass of meso-

dermic cells—the future lung—in the substance of which it repeatedly subdivides, until at last all the required innumerable little air-chambers and the passages leading into them have been excavated (see Chapter VII). Meanwhile, in the surrounding mesoderm blood-vessels have been forming, which become connected up with the heart and with the general circulation of the body by means of a pulmonary artery and a couple of pulmonary veins. It will be seen, then, from this brief account that the lungs arise very much in the same way as the liver, the treelike ramifications of the air-passages in the former closely corresponding to those of the bile-passages in the latter. And in both cases the passages are lined with endoderm, which fulfils, however, a very different function in each.

3. THE CIRCULATORY ORGANS

I have already explained in the preceding chapter how the blood-vessels are developed, viz. by the formation of a number of solid strands which afterwards become converted into hollow channels. I have also explained in Chapter VIII how in the Fishes, the Amphibians and the Reptiles, we are shown the various intermediate stages by which the originally quite simple tubular heart has been changed in the course of evolution into the much more elaborate one of the Birds and Mammals. I have now to add that in the embryonic development of the latter the heart passes practically through the same stages, once more exemplifying the truth of the Biogenetic Law, according to which the development of the individual repeats more or less faithfully the evolution which has taken place among its ancestors in past geological times. Thus in ourselves when the heart first appears it is little more than a simple tube, as in *Amphioxus*; then it becomes bent upon itself into a kind of , as in the fishes; while at the same time it shows a distinct division into an auricular and a ventricular portion. Later on partitions begin to form dividing each of these portions into a right and a left half, so that we get finally the well-known four-chambered arrangement.

Very interesting, too, is the way in which some of the principal arteries arise. In the fish there is a large blood-vessel which, proceeding from the anterior end of the heart, divides almost immediately into a right and a left branch. Each of these as it runs forward gives off laterally a series

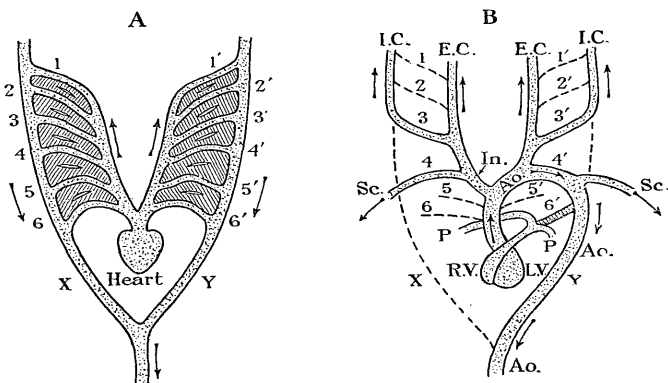


FIG. 24.—ARRANGEMENT OF PRINCIPAL ARTERIES IN FISH AND IN MAN.

A. *The Fish*.—The branchial arteries are shown on each side and the branchial clefts. For clearness, the gills and the capillaries belonging to them have been omitted.

B. *Man*.—The arrangement is fundamentally the same, but several of the branchial arteries have become aborted, their original places being indicated by the dotted lines. 3 and 3' now form portions of the internal carotids (I.C.). 4 has become the innominate artery (In.) and the right subclavian (Sc.), and 4' a portion of the aortic arch (Ao.) and of the left subclavian. 5 and 5' are both aborted, also 6, while 6' is represented by the blocked-up ductus arteriosus. Both 6 and 6' have given rise at their origin to the pulmonary arteries (P.P.). Sometimes in Man 4 and X form the aorta instead of 4' and Y—the normal condition in Birds. Or both arches may be present, as in Reptiles.

Ao., Aorta; 6' Ductus arteriosus; E.C. and I.C., External and internal carotids; In., Innominate artery; P.P., Pulmonaries; Sc. Sc., Subclavians; R.V., L.V., Right and left ventricles.

of smaller branches four or five in number, known as the *Branchial Arteries*, each of which following a curved path enters one of the visceral arches and there breaks up, as already explained, into a set of capillaries for supplying the breathing apparatus with blood. Presently, however, these capillaries unite into two main vessels, one on either

side, which after running backwards a certain distance join together in the middle line to form a single trunk. It is from this trunk that the newly oxygenated blood is distributed to all the posterior parts of the body.

Now in Reptiles, Birds and Mammals, which breathe with lungs instead of gills, we still find the above-mentioned branchial arteries, at all events to begin with; but instead of breaking up into capillaries, which in default of gills are of course no longer needed, they pass on intact through the visceral arches and become the two main vessels that unite lower down to form the single central trunk. A little later on, however, certain important changes set in, due to the abortion and subsequent complete withering up of several of the arteries in question. The interesting point is that in the case of Reptiles, Birds and Mammals, the final arrangement, whatever it may be, always betrays the fact that it has been derived from that much more primitive arrangement which remains persistent in the fish. Another interesting point is that occasionally even in a human being the final arrangement corresponds with that which normally occurs in a Bird or a Reptile, as though the embryo in this particular respect had not quite made up its mind what it was going to be.¹

The circulation of the blood in an unborn child pursues a course which differs very considerably from what it becomes afterwards. This is because the mother supplies the child by means of the Placenta with all that it requires in the way of food and oxygen, its own organs of digestion and respiration being still in process of formation. Besides, even if they were fully formed, they would clearly be unable to exercise their proper functions till after birth. Hence during the whole period of gestation the pulmonary circulation is in abeyance; no blood, or scarcely any, flows through the pulmonary vessels. But this being so, it may naturally be asked, How does the blood in the unborn child manage to complete its circuit? More particularly, How does it, after its return to the right auricle from the various parts of the body, manage to find its way across to the left

¹ Paterson, *Manual of Embryology*, pp. 265, 266.

side of the heart, seeing that the two sides of the heart are not yet in communication with one another by means of the pulmonary vessels? The answer is, that in the unborn child another kind of communication exists, an opening known as the *Foramen Ovale* having arisen in the partition which separates the right from the left auricle. I advisedly refer to it as "having arisen," for although at a much earlier stage the two auricles form but a single cavity, and it might be supposed, therefore, that the foramen ovale is simply a survival of that condition, this is not the case, for the orifice in question only appears after the complete closing up of the former passage of communication.¹

Again, in addition to the foramen ovale there are in the unborn child two other structural peculiarities which in an important manner affect the circulation.

1. First, there is a curious flap-like valve inside the right auricle, the effect of which is to permit two distinct streams of blood to pass through it with scarcely any intermingling.

2. And secondly, one of the branchial arteries on the left side known as the *Ductus Arteriosus*, and which along with others will afterwards become either blocked up or entirely obliterated, is allowed to remain open till a short time after birth—an arrangement by which it is possible for the blood to pass direct from the right ventricle into the descending portion of the aorta.

Bearing in mind these details, and with the aid of the accompanying diagram, there need be no difficulty in understanding the course taken by the circulation in the unborn child. It is as follows :—

The oxygenated blood on its return from the placenta by the umbilical vein goes first to the liver, and is thence conveyed by the inferior vena cava to the right auricle. Next, guided by the flap above referred to, it passes through the foramen ovale into the left auricle, and onwards at once into the left ventricle. From the left ventricle it is driven by the heart into the ascending portion of the aorta, and thence into those arteries the ramifications of which extend

¹ Gray's *Anatomy*, 20th ed., p. 115.

into the head and upper limbs and other anterior parts of the body. Coming back to the heart, the blood re-enters the right auricle by the superior vena cava, and without mixing there with the other stream passes immediately into the right ventricle, from which it is driven out through

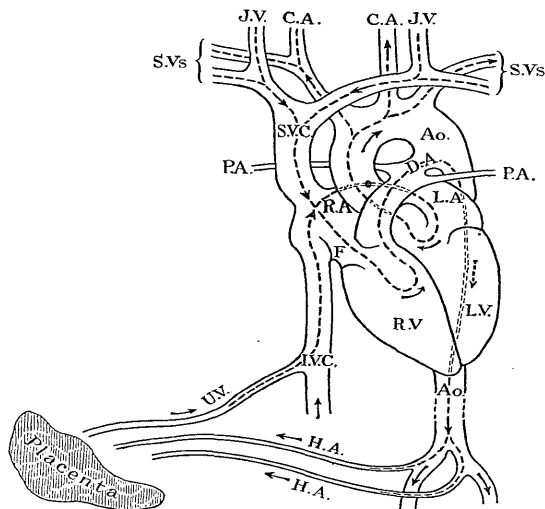


FIG. 25.—Course of the Fœtal Circulation (see text).—Ao., Aorta; C.A., Carotid arteries; D.A., Ductus arteriosus, which after birth closes up; F, Flap; H.A., Hypogastric arteries; U.V., Umbilical vein; J.V., Jugular veins; S.Vs., Subclavian vessels; S.V.C. and I.V.C., Superior and inferior venæ cavae; P.A., Pulmonary arteries (pulmonary veins omitted); R.A. and L.A., Right and left auricles; R.V. and L.V., Right and left ventricles.—Position of Foramen Ovale indicated by oval mark above and to the right of the letters R.A. Compare fig. 6, p. 80.

the ductus arteriosus into the descending portion of the aorta. Now it is this portion which with its ramifications not only supplies all the posterior parts of the body, but at the same time gives off the two branches, viz. the hypogastric arteries, which finally carry back the blood to the placenta to be re-oxygenated. It is also, as we have seen, while flowing through the placenta that the blood

receives from the mother all the nutriment, as well as the oxygen, needed for the growing child. The remarkable thing about this somewhat complicated arrangement is its purely temporary character. No sooner, in fact, is the child born than the circulation begins completely to change its course. This is effected in the following manner. First, the foramen ovale closes up, thereby preventing any further flow of blood from the right into the left auricle; and secondly, that portion of the ductus arteriosus which lies beyond the point where the pulmonary arteries branch off, becomes converted into a solid cord, and in this way stops the blood from passing direct any longer from the right ventricle into the descending portion of the aorta.

In consequence of these changes, whenever now the heart contracts, all the blood contained in the right auricle, whether received through the superior or the inferior vena cava, is forced into the right ventricle, and is immediately afterwards compelled to flow through the two pulmonary arteries into the lungs. Moreover, in response to the child's efforts to breathe, the lungs begin for the first time to discharge their proper function and to take over from the placenta the task of oxygenating the blood. Again, it is no longer through the placenta that the mother supplies her child with food; she supplies it now in the form of milk, which by a remarkable provision is just at this time produced from her breasts.

In the above description I have purposely introduced a considerable amount of detail, because as it seems to me we are presented here with a very striking illustration of the extraordinary ingenuity of the means which Life sometimes employs for the accomplishment of her ends. We have seen in the case of the higher animals that in order to protect the embryo during its early developmental stages, the plan has been adopted of detaining it for a longer or shorter period inside the body of the mother. But inasmuch as at every stage of its existence an organism requires both food and oxygen, this plan has necessitated special means for supplying it with these, so long as the period of detention lasts. Hence in Reptiles and in Birds both a Yolk-sac and

an Allantois¹ have made their appearance, the functions of which have been taken over in mammals by that very important organ, the Placenta. The placenta, however, would be quite unable to discharge these functions apart from those quite temporary little structural arrangements mentioned above, which during the months preceding birth cause the blood, as it circulates through the arteries and veins, to pursue a course so very different from what it afterwards takes. The wonderful thing here is the conspiracy, so to speak, of all the parts concerned for the attainment of the required end, and the way in which the whole arrangement is dispensed with at the time of birth.

4. THE ORGANS OF MOVEMENT

These, like the circulatory organs, are all developed out of the mesoderm, and include not only the muscles, but, as was explained in Chapter IX, the tendons, bones, ligaments, articular capsules and cartilages as well, all of which have an important part to play in connection with movement. With the exception of the muscles they are all composed of some variety of connective tissue, the chief peculiarity of which is that its constituent cells have surrounded themselves in the course of their development with a more or less solid matrix.

As it would be impossible, however, to deal here with all the organs concerned in movement, I shall restrict myself to a brief account of what takes place in the development of bones. In by far the majority of cases they are constructed out of previously developed pieces of cartilage, which in their shapes and relative sizes almost exactly resemble them, and which may be said, therefore, collectively to prefigure the future skeleton. As to what causes these cartilaginous pieces—"cartilaginous models" one might perhaps call them—to acquire these their proper shapes and right relative sizes, and to appear in their correct positions in the body, we are entirely in the dark, and are again brought up face to face with one of those many mysteries

¹ The yolk-sac is also found among fishes, but not the allantois.

encompassing the whole subject. All that we know is that everything happens as just stated. Especially remarkable, too, is the process by which these cartilaginous models are afterwards transformed into bones. Though each in itself is devoid of blood-vessels, it is closely invested with a sheath of connective tissue, viz. the *Perichondrium*, which is full of them. In this sheath a number of special cells arise known as *Osteoblasts*, which, after applying themselves to the outer surface of the cartilage, proceed to deposit on it a succession of bony layers, the materials for which are of course supplied by the blood. It is these osteoblasts, therefore, which are the true bone-formers.

Ossification, however, is not confined to the outer surface of the cartilage. The cartilage cells in the interior have for some time past been rapidly multiplying, arranging themselves in longitudinal rows and scooping out little hollow spaces in the matrix around them. Meanwhile, owing to their activity the matrix has become gradually hardened by being impregnated with phosphate of lime. This, however, is merely preparatory to the formation of true bone, which can only be carried out by the aforesaid osteoblasts, the ordinary cartilaginous cells being quite unequal to the task. Consequently, after a certain time the latter shrivel up and die, leaving behind them the little spaces which they have created, and which, because of their longitudinal arrangement and increased size, have now begun to run together and to form long irregular channels. These may be regarded as the precursors of the Haversian canals, as also of the large central cavity in which the marrow and the principal nutrient vessels will afterwards be lodged. As to the osteoblasts, they are not derived from any development of them occurring *de novo* in the interior of the cartilage, but from those which have already been actively at work in the perichondrial sheath. At a particular place, generally about the middle of a long bone, they force a passage into its interior, carrying with them a number of blood-vessels, and also certain other cells different from, and considerably larger than, themselves, known as *Osteoclasts* or bone-destroyers. These latter finish the work begun by the now

defunct cartilage cells. Thus they break down the remaining partitions between the hollow spaces mentioned above, and by constant removal of material complete the central cavity. Meanwhile, the osteoblasts are busily engaged in the production of bony substance, with which they bit by bit replace the pre-existing cartilage. It is unnecessary, however, to go into any further details. It is enough to state, that as the result of the activity of these two quite different classes of cells—the bone-formers and the bone-destroyers—all that elaborate structure which was described in Chapter XIII is gradually developed, consisting, that is, of the numerous interconnected Haversian systems, each furnished with its central canal, its lamellæ, its lacunæ and its canaliculi. As for the bone-cells which are afterwards observed inside the lacunæ, they are really the osteoblasts, which have managed to find in these minute microscopic interstices their final resting-place.

We have next to consider the way in which the bones grow, a process which is continued, of course, long after birth. Now with nearly all the other organs in the body it is comparatively easy to understand how increase in size can be effected, viz. by the incessantly repeated subdivision of their cells. But with a hard and rigid structure like a bone there are certain obvious difficulties to be overcome, and particularly in connection with its increase in length. But, first, as to its increase in thickness. This is accomplished by the renewed activity of the osteoblasts in the perichondrium, or, as it is henceforth termed, the *Periosteum*. These go on depositing fresh material on the external surface of the bone, while internally the osteoclasts are busy at their old task of removing material and so enlarging the central cavity. Hence this curious result often follows, that in a fully grown bone hardly anything may remain of its original substance at the time of birth. This enlargement of the central cavity is in part, no doubt, in order to prevent the bone from becoming too heavy, without detracting from its strength.

As to the increase in the length of a bone the matter is not quite so simple, being complicated by the fact that in

so many instances a bone is irregularly shaped. Take, for example, the *Femur* or great thigh bone. Below, it is considerably enlarged just above and in connection with the knee-joint, while at its other extremity, at the hip-joint, its

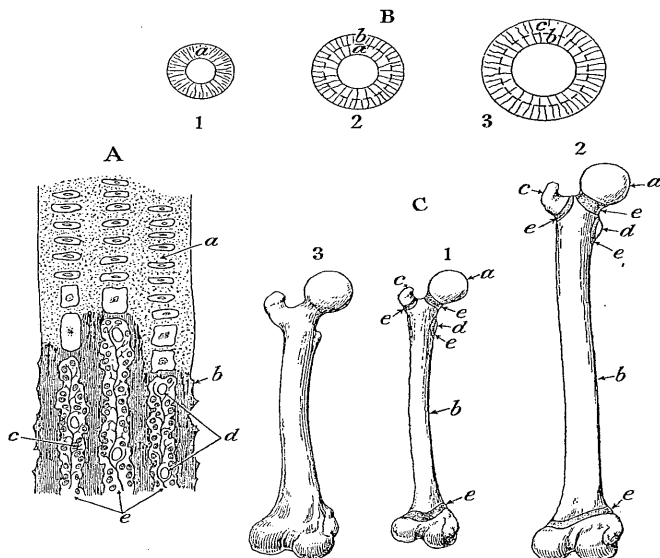


FIG. 26.—A. Development of Bone, small piece much magnified. *a*, Cartilage and cartilage cells; *b*, Bone; *c*, Osteoblasts; *d*, Osteoclasts; *e*, Formation of Haversian canals with blood-vessels.

B. Growth of Bone in thickness. *a*, *b*, *c*, successively added layers. At stage 3, *a* has been completely removed, thereby enlarging central cavity.

C. Growth of Bone (femur) in length. *a*, Head at hip-joint; *b*, Shaft; *c* and *d*, Great and little trochanters; *e*, Intervening cartilages. 1, An earlier stage; 2, Ditto later; 3, Result, if the cartilages had ossified.

rounded head is borne at the end of a piece of bone which is by no means in a straight line with the main shaft. If, therefore, the cartilage which is destined afterwards to become the femur were completely ossified, say, at birth, plainly it could not go on increasing in length and at the same time retain its proper shape. What happens, then, is

this. The ossification, which begins in the middle of the shaft and proceeds from that point both upwards and downwards, slows off as it approaches the two joints, leaving, at a short distance from each end, a piece of cartilage, which is still capable of increasing in length as well as in thickness. Meanwhile, two other centres of ossification have appeared, one near the hip and the other near the knee; but the two bony masses which are formed from these do not permanently unite with the main mass in the shaft till the adult stage has been practically reached. Previous to that they are only united to it by the two pieces of intervening cartilage just mentioned. By this remarkable device the problem is solved, and a long bone such as the femur is enabled, in spite of its irregularities, to attain its full length without undergoing any material change of shape. It should be added, perhaps, to the above description that in the femur there are two other centres of ossification, although both of minor importance, one, namely, for each of the two *Trochanters*, which are a couple of protuberances near its upper end for the attachment of certain muscles.

As to the other organs in the body concerned with movement—the muscles, tendons, ligaments, etc.—I must refrain, as already said, from giving any account of their development, as it would draw out this chapter to an inordinate length.

5. THE ORGANS OF CO-ORDINATION AND CONTROL

These constitute the Nervous system, and are developed from the neural tube, which, as we have seen, is formed from a longitudinal strip of ectoderm that at an exceedingly early stage is folded off from the rest of the ectoderm on the dorsal side of the body. By a gradual thickening of its walls this tube eventually becomes the spinal cord except at its anterior end, where three dilatations occur arranged in serial order, the so-called *Cerebral Vesicles*. These give rise respectively to the fore-brain, the mid-brain and the hind-brain, which were briefly referred to in Chapter XI. As I do not intend, however, to enter into any detailed description of the highly complicated changes through which

the nervous system passes, I shall confine attention to just a few special points.

The channel running up the centre of the neural tube

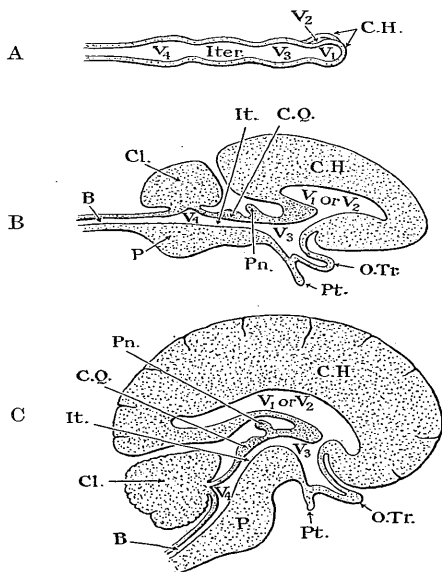


FIG. 27.—DEVELOPMENT OF BRAIN.

- A. Front end of Neural Tube, with its three primitive vesicles and rudimentary cerebral hemispheres.
 B. Sagittal section of Brain of ordinary Mammal. The tube has now become bent in various ways and its walls considerably thickened in certain parts.
 C. Sagittal section of Human Brain.
 B., Bulb; C.H., Cerebral Hemispheres; Cl., Cerebellum; C.Q., Corpora quadrigemina; Pt., Pituitary body; It., Iter leading from 4th to 3rd ventricle; O.Tr., Optic tracts; P., Pons; Pn., Pincal body, erroneously supposed by Descartes to be the seat of the soul; V_1 , V_2 , V_3 , V_4 , Ventricles. Note V_1 and V_2 are a pair of lateral ones not actually in the section.

becomes reduced in the spinal cord to an extremely narrow passage owing to the thickening of the walls just mentioned; but in the brain, and more particularly in the fore-brain and the hind-brain, it opens out into cavities of consider-

able size, viz. the four ventricles,¹ which, of course, must not be confused with the ventricles of the heart. Moreover, in the different parts of the brain the walls of the original tube become very unequally thickened, and indeed in certain places they remain so thin as to be little more than mere membranes. This is due to the unequal multiplication of the cells composing them.

At an early period the fore-brain gives rise in front to a pair of outgrowths which, although very small at first, become afterwards in Man so enormously developed as to exceed in bulk all the other parts of the brain put together. These are the cerebral hemispheres, and are of quite exceptional importance, because, as we have every reason to believe, the grey matter which forms their outer crust is the seat of consciousness. But it is unnecessary to repeat what has been said upon this subject in Chapters XI and XIII.

It was also previously pointed out that the chief peculiarity of the neurones, or cells composing the Nervous System, is that they are provided with those remarkable thread-like appendages known as dendrons, axons and collaterals, by means of which they not only enter into relations with one another, but reach out in the case of the axis-cylinders of nerves to the most remote parts of the body, such as the tips of the fingers and the soles of the feet. It must be remembered, too, that these cells, so far as their microscopic appearance goes, are at first just like all other cells; it is only as development proceeds that they put forth these extraordinary prolongations of their substance. And the wonderful thing is, not so much that they should do so, but that each of these nervous prolongations should infallibly find its way out through all the intervening tissues and arrive at last, often by a somewhat circuitous route, at its true destination—either the muscle which it is afterwards to actuate, or the sense-organ from which it is afterwards to carry up certain impressions to the brain. That this is what really occurs has been disputed by some, but the balance of opinion is all the other way. If, then,

¹ See Chapter XI, p. 123.

it is really a fact, it is surely a most astounding one, and only serves to deepen the profound mystery with which the whole subject of the development of the individual is encompassed.

6. THE ORGANS OF SENSE

We will consider first the eyes, and secondly the ears.

(4) In Man, and in the Chordates generally, the eyes make their first appearance as a pair of outgrowths of the fore-brain, originating, therefore, in much the same way as the cerebral hemispheres. Two tubular structures, the so-called *Optic Stalks*, are shot out in front, both of them ending in a hollow bulb. Each stalk eventually gives rise to one of the optic nerves; whereas the bulb is gradually transformed into the retina, including the pigment layer, which, it will be remembered, comes immediately behind the layer of the rods and cones (see Chapter X). The transformation begins with an invagination of the bulb on that side of it which is farthest from the brain and is therefore directed outwards. The effect of this is to obliterate the internal cavity of the bulb and to convert the bulb itself into a kind of cup—the *Optic cup*. The process, in fact, is not unlike that which occurs in the formation of the gastrula in *Amphioxus* and in many other animals. The cup, be it observed, is necessarily composed of ectodermic tissue, as it is derived from the ectodermic tissue of the brain. Again, as the result of the invagination, the cup, just like the gastrula, consists of two layers, and of these the outer one becomes differentiated into the pigment layer, and the inner one into the retina proper. Meanwhile, over two restricted areas on the outer surface of the body, in that part of it which will ultimately become the face, and exactly opposite the cups, two other invaginations occur. At first they are mere depressions, then pits, but presently, having grown deeper, they detach themselves completely from the outer surface and become changed into a pair of hollow vesicles, each of which at this stage presents the appearance of being clasped by the rim of the cup opposite to it. Now these little vesicles are really the rudiments of the eye lenses,

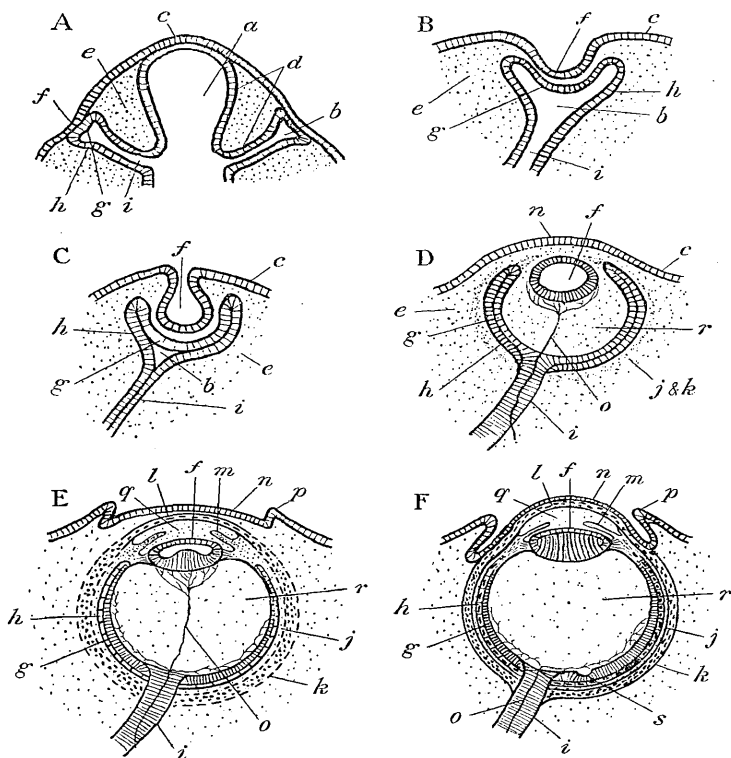


FIG. 28.—THE DEVELOPMENT OF THE EYES.

A. Early stage: Fore-brain, Optic Stalks and Optic Vesicles.

B-F.—Later stages in development of Right Eye. *a*, Fore-brain; *b*, Optic vesicle, afterwards becoming optic cup; *c*, Superficial ectoderm; *d*, Ectoderm derived from that lining the neural tube; *e*, Mesoderm; *f*, Lens; *g*, Retina; *h*, Pigment layer; *i*, Optic stalk, afterwards becoming optic nerve; *j*, Choroid; *k*, Sclerotic; *l*, Cornea; *m*, Iris; *n*, Conjunctiva; *o*, Artery for nourishing lens before latter fully formed, afterwards only nourishing retina; *p*, Eyelid; *q*, Aqueous humour; *r*, Vitreous humour; *s*, Yellow spot.

Compare fig. 10, p. 107.

into which they are step by step transformed by the following changes: (a) The cells of each on that side of it which is turned towards the cup elongate greatly in the forward direction, till at last they quite fill up the hollow space inside, and thus convert the vesicle into a solid structure; (b) this structure, though it remains spherical in the fish, slowly takes on in most of the higher forms a biconvex shape, and (c) becomes transparent.

After this, on each side of the middle line of the face there is yet another invagination of the superficial ectodermic cells. They fold inwards in order to form the inner lining of the upper and lower eyelids, and also the *Conjunctiva*, which is the thin transparent membrane stretched across the front of, and adhering to, the cornea. Now all these parts are, as we have seen, derived in one way or another from the ectoderm; and the same holds true to a certain extent of the ciliary processes and the iris, to the formation of which the rim of the optic cup apparently contributes. Moreover, according to some the vitreous humour is likewise in part derived from the ectoderm, being due to the activity of certain cells in the front layer of the retina. As for the two outer coats of the eye, the sclerotic and the choroid, and their prolongations forward as the cornea and the iris (in part), they are of mesodermic origin; and so also are the muscles which move the eyeball, together with the bony cavity or orbit in which the eye is placed. The accompanying diagram is intended to illustrate the successive stages in the development.

(B) We pass on to the ears. Each consists of three parts: an external, a middle and an internal ear. The first of these includes the outside projecting portion of the ear known as the *Concha* or shell, and the passage extending inwards from it as far as the drum. On the inner side of the drum comes the *Tympanic Cavity*, or middle ear, which is hollowed out in the substance of the temporal bone. It contains air, and every time we swallow is put in communication with the atmosphere outside by means of the *Eustachian Tube*, which leads down into the pharynx. Stretched across this cavity is the little chain of bones

previously mentioned, viz. the hammer, the anvil and the stirrup bones. They articulate with each other and serve to transmit the vibrations of sound from the drum to a somewhat similar membrane which separates the middle from the internal ear. They also magnify the vibrations.

The internal ear is filled with a special liquid, and consists of the *Osseous* and the *Membranous Labyrinths*. The former includes the *Vestibule*, the *Cochlea* and the *Semi-*

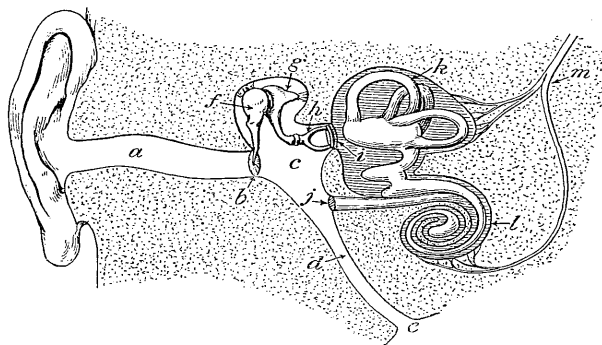


FIG. 29.—The Ear (diagrammatic). *a*, External ear; *b*, Drum; *c*, Middle ear or tympanic cavity leading down by *d*, the Eustachian tube, to *e*, the Pharynx; *f*, *g*, *h*, Hammer, anvil and stirrup bones; *i*, *j*, Oval and round "windows," each closed by a membrane similar to the drum; *k*, semicircular canals; *l*, Cochlea, true organ of hearing; *m*, eighth cranial nerve, supplying canals and cochlea.

circular Canals—all very curiously shaped passages continuous with one another and, like the middle ear, hollowed out in the substance of the temporal bone. Floating in the special liquid is the membranous labyrinth which, though smaller than the osseous labyrinth, corresponds to it in its general form. The cochlea with its spirally wound internal passage resembles somewhat the shell of a snail. It is the true organ of hearing, and from it proceeds the principal branch of the auditory nerve. The semicircular canals, on the other hand, are apparently not concerned with hearing,

but are for the purpose of giving us the sense of direction, and that we may be guided thereby in our various locomotory movements. They are three in number, and are set at right angles to one another with obvious reference to the three-dimensional character of space. The other main branch of the auditory nerve takes its rise from them.

Of the three parts just described the internal ear is by far the most important, and is naturally, therefore, the first to make its appearance in the course of the embryonic development. It was also the first to be evolved in the past history of the Chordates; and indeed before the advent of the tailless Amphibians—the frogs and the toads—it was the only part of the ear which existed. Moreover, in the Hags, which are very low down among the Fishes, there is only one semicircular canal; in the Lampreys, which come next above them in the scale, there are two; whilst the third was not added till the advent of the higher fishes, which, as distinguished from their round-mouthed predecessors, are provided with proper jaws. Again, till the arrival of the Mammals the cochlea was only very imperfectly formed.

As to the middle ear, a stirrup bone was first developed among the lower amphibians; a little later a second bone was added, and so a state of things arose which continued during the evolution of the Reptiles and the Birds, until at last the Mammals appeared with the little set of three bones all complete. The tympanic cavity itself, with its drum and its Eustachian tube, was not evolved till the tailless Amphibians dawned upon the scene, though among the snakes, which are a degraded race of Reptiles, it degenerated, and to this day is still wanting in them. It is present, however, in all the other classes of Reptiles, as well as in the Birds and the Mammals.

The external ear was the last to be evolved, for to begin with, the drum was flush with the outer surface of the head. In some of the Reptiles it began to sink inwards; in the Birds it sank still further, and became surrounded with a circlet of feathers; whilst in the Mammals, with the

exception of the Monotremes, which form their lowest division, the concha was finally added.

Now this rapid survey of the various stages through which, as we believe, the ear has passed in the course of its evolutionary history, affords perhaps as good an illustration as any of the kind of facts on which the modern theory of Common Descent is based.

In the development of the individual organism—the subject to which we now return—the internal ear is, as already stated, the first to make its appearance. There is an invagination of the outer skin, that is, of the ectoderm, which beginning as a mere pit becomes gradually deeper till, just as in the formation of the lens of the eye, it separates itself off as a hollow vesicle. Its subsequent history, however, is entirely different. Instead of becoming solid and transparent and taking on a biconvex form, it remains hollow to the end, and undergoes a most marvellous series of changes in shape, until eventually it is converted into the highly complicated membranous labyrinth with its snail-like cochlea and three semicircular canals. The wonderful thing is, that two apparently similar little pieces of ectoderm should separate themselves off like this from the outer skin, and that one of them should develop into the lens of the eye, and the other into such a totally different kind of organ as the membranous labyrinth. What is there in these two little pieces of ectoderm, originally so alike, to account for their extraordinary difference of behaviour?

The external ear, or rather the passage leading up to the drum, is produced by a second invagination of the ectoderm, but in this case no hollow vesicle is formed, but a deep depression which always remains open.

The middle ear has a very curious history, being intimately connected with that of one of the branchial clefts, the rest of which close up after appearing for a short time. It results from an evagination of a portion of the endoderm lining the pharynx, which by pushing its way upwards and backwards forms the Eustachian tube, and ends by interposing a cavity between the internal and external ears.

It only remains to add that the temporal bone itself, in

which all these remarkable structures are so carefully hidden away, is like every other bone in the body of mesodermic origin. Thus ectoderm, mesoderm and endoderm, the three primary embryonic layers, all contribute to the formation of the organ of hearing, the same being true of the drum of the ear in spite of its extreme thinness.

CHAPTER XVII

IN SEARCH OF AN EXPLANATION

IN the three preceding chapters it has been impossible to do more than touch the fringe of a very large subject. I hope, however, that enough has been said to convey a sufficiently correct impression of that most marvellous process by which, not only in ourselves but in all animals except the lowest, the original microscopic germ-cell is gradually transformed into the fully grown organism. But here as elsewhere the human mind refuses to be satisfied with the mere registration of facts; it demands an explanation of them, and in this particular instance, the facts being of so extraordinary a kind, the demand becomes peculiarly insistent. What is the nature of that mysterious cause which somehow hidden in the germ-cell compels the embryo to pass with such unfaltering precision through all its successive developmental stages? And how is it that for final result we have an organism which, with its numerous exceedingly diverse and highly complicated parts, corresponds so exactly, or so nearly exactly, to the parental form?¹

The full nature of this problem and of the many difficulties with which it is beset will best perhaps be understood by considering a few of the more notable attempts which have been made to tackle it.

I propose, therefore, in the following pages to give some

¹ "The increase of structure, the production of form out of the relatively formless germ, and the gradual passing of this into a new individual which is like the parents that gave it birth, this is the marvel which has always excited the wonder of the observer, and demands all his wit to understand and to explain."—Jenkinson, *Experimental Embryology*, p. 279.

"The constitution of living cytoplasm seems to be normally that of a thick colloid solution. . . . It baffles our imagination, however, to conceive how a solution can be the seat of internal structure, and how in particular a nerve cell with all its inherited and acquired aptitudes . . . can be in life nothing more than a thick syrup."—E. W. McBride in the *Encyclopædia Britannica*, vol. xxx, p. 785.

short account of them, so that we may be able to judge for ourselves with what measure of success they have been attended, and to what extent, if any, they have brought us within sight of the desired solution. As a fitting introduction to the subject I will begin with Darwin's theory of *Pangenesi*s, though there can be no doubt that, if he were now alive, he would see every reason to modify it, in view of all that has been discovered since his time.

According, then, to the theory of *Pangenesi*s, all the cells in the body are continually throwing off multitudes of excessively small particles known as *Gemmules*, each cell producing its own set, its own distinctive kind. Whirled away from their places of origin by the general blood-stream, they are conveyed to the reproductive organs, and in such a manner as that in the male every spermatozoon, and in the female every ovum, is furnished with a complete assortment of them. Hence, whenever a spermatozoon and an ovum unite, as in the act of fertilisation, the resulting germ-cell is provided with gemmules proceeding from, and representative of, all the cells in the two parent organisms. And the theory is that, as the embryo gradually increases in size, each particular set of gemmules gives rise to cells which correspond in character with the cells, or rather with the pairs of cells, from which that particular set has been derived. Thus the structural complexity of the two parent organisms is, so to speak, secretly passed on through the minute and apparently simple germ-cell, to reveal itself again in the structural complexity of the offspring.

Now the first objection to this theory is its extremely hypothetical character. There is practically nothing, so far as microscopic evidence goes, to suggest that any such particles as these gemmules exist, and still less that they behave in the manner described. In this respect the theory differs materially from those which have been propounded since, and which have all more or less been based on certain observed facts.

Another objection to the theory is that in endeavouring to solve one problem it raises up so many others. For example, How is it, we ask, that the different kinds of

gemmules, in whatever parts of the body they may have been produced, should so infallibly find their way into the reproductive cells? What is it that secures this result? For obviously if any one of the different kinds failed to reach the germ-cell, the part to which they would otherwise have given rise would be missing in the offspring; or if they reached it only in feeble numbers, the part in question would be very imperfectly developed.

Again, there is the serious difficulty connected with the well-established fact that mutilations are not inherited. Thus in an experiment in which the tails of mice were for several generations persistently cut off, it was found that the young were not in the smallest degree affected by it; they were all born with tails notwithstanding. Such a result, however, is clearly irreconcilable with the theory of Pangenesis, for in mice so treated all the tail-bearing gemmules would, of course, be wanting. Other instances, too, might be quoted. Thus, although till recently the custom had long prevailed among the Chinese of tightly bandaging their women's feet, and although circumcision has been practised among the Jews for many thousands of years, in neither case has it produced the least effect upon their offspring.

Once more, granting for the sake of argument that gemmules exist, and that in the germ-cell all the different kinds required for the construction of the body have in some inscrutable manner become congregated together, how far would this supposition really help towards a solution of the main problem? We are to picture to ourselves the germ-cell as the meeting-place of an immense number of infinitesimally small particles variously endowed, some of them destined to produce bone-cells, others muscle-cells, others nerve-cells and so on, or it may be cells of such a highly specialised kind as those which enter into the construction of the rods and cones in the retina. What we want to know, however, and what the theory in question fails to explain, is, How out of such a confused medley, such an unorganised assemblage as this, could the highly organised body of an adult individual arise? What is there to direct the gemmules as they set about their task, causing

for example the femur, as the result of their activity, not only to be composed of bony substance, but to be of its exact right size, its exact right shape and in its exact right position in the body? Or on this theory what is there to prevent liver-cells from developing sometimes inside the skull, or a pair of eyes from making an unexpected appearance on the surface of the abdomen? Pangenesis, in short, can give no answer to such questions, for what it proposes is just as though a bag, containing a number of different kinds of seeds indiscriminately mixed together, should be shaken out on a garden plot, and in a few weeks' time flowers of every variety of form and hue should be seen coming up, not confusedly, but arranged in a very definite and intricate pattern.

As an escape from some at least of the above difficulties the idea has been suggested that, whatever may be the hidden thing lodged in the germ-cell which is the cause of its subsequent development, it must be possessed of some kind of definite structure, it must consist of parts architecturally related to one another and collectively prefiguring, as it were, the adult organism.

An idea of this sort, but a very crude one, was put forth even in pre-Darwinian days. It was supposed by some that, although the embryo, to begin with, was quite invisible owing to its extreme smallness, it was nevertheless an exact, a complete miniature of the fully developed organism—a miniature, therefore, which to attain the mature condition had simply to grow or increase in size. But, as the foregoing chapters will have abundantly shown, such a supposition is in no sort of agreement with the observed facts. For if that were so, then there ought to come a time, for instance, in our own embryonic development, when the hitherto invisible little mannikin should be clearly seen emerging into view, completely furnished with all its external parts and internal organs, though of course they would still be very small. But this is not what happens. To begin with, what we see is a round little cell, which by a series of rapid divisions leads to the production of a morula, but this, far from bearing any resemblance to a

human being, is still of a roughly spherical shape and is composed of parts practically all alike. If afterwards it gradually assumes a more manlike appearance and comes to be possessed of a number of internal very elaborately constructed organs, this is only as the result of an extremely complicated set of changes, in which layers and whole masses of cells are shifted about from one position to another, as occurs, for instance, in the development of the spinal cord and the brain, of the eyes, the ears, the lungs and the alimentary canal.

But although, for the above reasons and for others which might be given, no one to-day would think of reviving the so-called *Preformation Doctrine*, as thus crudely conceived, there are other versions of it of a later and more refined type which have gained a certain amount of acceptance, and in which the idea prevails that there must be present within the germ-cell some sort of an organised structure to account for the organised structure to which it will ultimately give rise. Of these versions the most famous perhaps, as well as the most elaborate, is that of the late distinguished German biologist, August Weismann, who fully expounded his views in his two volumes on *The Evolution Theory*, as also in his earlier work entitled *The Germ Plasm*.

Now to whatever extent, as we shall see by and by, his views are open to criticism, it is very desirable to gain some acquaintance with them, because by doing so we shall come to realise better perhaps than in any other way the extreme difficulty of the problem to be solved. Before entering, however, on any discussion of them, there are several important facts to be considered all bearing on the subject, and to these we must more particularly confine attention in the present chapter.

I have already described that most marvellous process by which in all ordinary cases a cell divides, though it may be as well if at this point the reader will turn back to Chapter XV to refresh his memory. We there saw that whenever such a division occurs, each chromosome splits longitudinally into two halves, which afterwards go their

separate ways, one to each of the two new daughter-cells, or, more precisely, to each of the two newly formed nuclei. Because of this, the number of the chromosomes is invariably the same in every cell of the body, however many times the act of division may have been repeated ; and, further, it is always equal to the number of the chromosomes which were present in the original germ-cell.

To this rule, however, the reproductive cells, viz. the spermatozoa and ova, form a remarkable exception, the chromosomes in each of them being exactly, or all but exactly, half the normal number. So we naturally ask : How are these reproductive cells produced, and how and when is the reduction in the number of their chromosomes effected ?

Let us consider first the spermatozoa. Like all other cells in the body they trace back their descent to the original germ-cell, although they are generally separated from it by a large number of intervening generations. These intervening generations form what has been described as the *Germ-track*, and they consist of cells which differ apparently in no essential respect from all other cells. Ultimately, however, they give rise to a special set known as the *Primary Spermatocytes*, each of which presently divides into a pair of *Secondary Spermatocytes*. Now it is during this division that the halving process just referred to takes place.

To fix our ideas, let us choose some animal which, like the fruit-fly (*Drosophila*), has for the normal number of chromosomes in each of its cells exactly eight ; eight, therefore, will be present in each of its primary spermatocytes. When, however, one of these last divides, the chromosomes, instead of splitting into halves, conjugate with one another—that is, join up in pairs, the members of each pair coming to lie side by side in closest juxtaposition, and often twisting round one another in a peculiar fashion, as will be described more fully later on (Chapter XIX). This done, they draw apart again, and *without undergoing any division* travel towards the poles of the achromatic spindle, half of them towards one of the poles and half of them towards the other, so as to form the nuclei of the two new daughter-cells. Hence

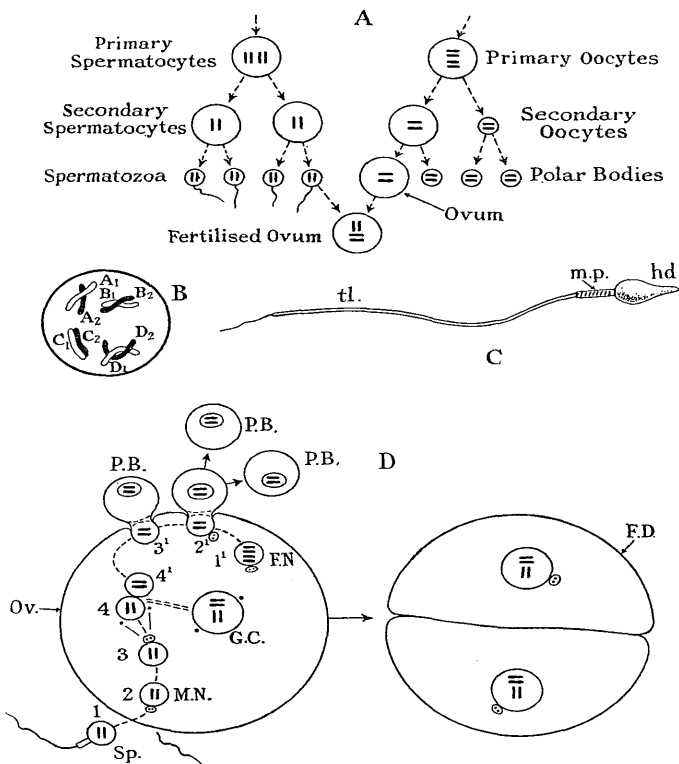


FIG. 30.—MATURATION AND FERTILISATION.

- A. General diagram. For explanation see text. Number of chromosomes in all ordinary cells supposed to be four.
- B. Chromosomes conjugating, paternal ones coloured white, maternal ones black. In this case eight in all present.
- C. Spermatozoon, human and greatly magnified. hd., Head; m.p., Middle piece; tl., Tail.
- D. Fertilisation and first division of Germ-cell (after Wilson). Ov., Ovum; Sp., Spermatozoon; M.N., Male nucleus; F.N., Female nucleus; P.B., Polar bodies; G.C., Fertilised Germ-cell; F.D., Result of first division 1-4, Progress of the male nucleus; 1'-4', progress of the female nucleus. At 4, 4', the two nuclei have met to form the nucleus of the Germ-cell (G.C.), when the normal number of the chromosomes is restored. Four chromosomes in all present.

it follows that each daughter-cell—secondary spermatocyte—contains four chromosomes only. There is, I may add, evidence to show that in the conjugating process each chromosome joins up, not with *any* of the rest, but always with that particular one which may fitly, therefore, be described as its “mate.” So if we choose to employ as symbols for them the letters $A_1, A_2; B_1, B_2; C_1, C_2; D_1, D_2$, we shall, besides drawing attention to the fact that they exist in pairs, indicate also that, inasmuch as A_1 always conjugates with A_2 , and B_1 with B_2 , and so on, it is probable that the members of each pair much more closely resemble one another than they do any of the rest.

Now what is true of the fruit-fly, and of other forms in which differences between the chromosomes can be microscopically made out, may fairly be assumed to be true universally, and especially as there are several other facts recently brought to light which point to the same conclusion. Provisionally, then, we may conceive of the chromosomes in the cells of all organisms, whether animals or plants, as existing in pairs, and, whenever the time comes, as conjugating accordingly.

But there is another point of importance in connection with this subject. When a primary spermatocyte divides and the members of each pair of chromosomes after conjugating part company—and in such a manner as that each of the two daughter-nuclei receives an A , a B , a C and a D —we must not suppose that all the resulting groups will necessarily be represented by A_1, B_1, C_1, D_1 , and A_2, B_2, C_2, D_2 . They may separate out in eight different ways, and by so doing give rise to no less than sixteen different combinations, thus :

$A_1 B_1 C_1 D_1$	and	$A_2 B_2 C_2 D_2$
$A_1 B_1 C_1 D_2$	„	$A_2 B_2 C_2 D_1$
$A_1 B_1 C_2 D_1$	„	$A_2 B_2 C_1 D_2$
$A_1 B_1 C_2 D_2$	„	$A_2 B_2 C_1 D_1$
$A_1 B_2 C_1 D_1$	„	$A_2 B_1 C_2 D_2$
$A_1 B_2 C_1 D_2$	„	$A_2 B_1 C_2 D_1$
$A_1 B_2 C_2 D_1$	„	$A_2 B_1 C_1 D_2$
$A_1 B_2 C_2 D_2$	„	$A_2 B_1 C_1 D_1$

Hence, should there be, as is probable, certain slight differences between the members of each pair— A_1 , for example, being not quite the same qualitatively as A_2 —each of the above combinations will be slightly different from the rest; and if, as is also probable, the precise assortment of the chromosomes depends on chance, then among a sufficiently large number of secondary spermatocytes the above combinations will exist in approximately equal numbers.

The important consequences of what has just been said will only appear later on. It remains here simply to add that the number of the possible combinations becomes vastly increased, as we pass from organisms which, like the fruit-fly, have only 4 pairs of chromosomes in each cell to those which have 6, 10, 16 or even more. The rule is, that if the normal number of the pairs of chromosomes be n , then the number of the possible combinations will be 2^n . This means that in the human species, with its 24 pairs of chromosomes, the number of the possible combinations will be 2^{24} —that is, there will be nearly 17 millions of them.

The next stage in the development of the spermatozoa is reached when the secondary spermatocytes themselves divide—each of them into two daughter-cells known as *Spermatids*. When this happens—we are still taking the fruit-fly for our example—each of the 4 chromosomes splits longitudinally into two halves, as in ordinary cell-division, and these halves separating from one another go their respective ways to form the nuclei of the two spermatids. Hence each of these nuclei, like the nucleus of the secondary spermatocyte, which by its division has just given rise to them, also contains 4 chromosomes, and is therefore similarly constituted.

After this, there is no further division of either cells or nuclei, but each spermatid becomes converted into a spermatozoon, although in a manner much too complicated to be described here.¹ From all this we learn that a primary spermatocyte produces by its successive divisions four spermatozoa, each of which contains half the normal

¹ Wilson, *The Cell in Development and Inheritance*, p. 134.

number of chromosomes. And the same holds true in the case of every member of the Animal Kingdom, whatever may be the number of the chromosomes distinctive of its species.

In Man the spermatozoa are exceedingly minute tadpole-shaped bodies, each measuring about $\frac{1}{500}$ th of an inch in length, inclusive of its tail. There are said to be over 60,000 of them in a single drop of the seminal fluid,¹ any one of which is quite sufficient to fertilise an ovum and so give rise to a human being. A spermatozoon consists of a head, a middle-piece and a tail. The head is oval in shape, somewhat flattened, and consisting practically of nuclear material only. It contains, therefore, the chromosomes—the reduced number of them, of course. Moreover, it is provided in front with a kind of cap having a sharp edge, with which, when fertilisation takes place, it pierces the outer membrane of the ovum. In some animals, as for instance in the salamander, it is provided for the same purpose with a spear-like projection covered with barbs.²

The middle-piece is rather longer than the head, and has given rise to a considerable amount of controversy. It is believed by many to contain the centrosomes, or, if not the centrosomes, structures closely corresponding to and derived from them.

The tail is at least ten times longer than the head, and is very slender. It is extremely active, and by its lashing movements is continually propelling the spermatozoon onwards, if by any chance it may meet and fertilise an ovum.

The ova are developed in the female much after the same manner as the spermatozoa in the male. Thus a certain stage is reached at which the cells belonging to the germ-track produce what are known as the *Primary Oocytes*. In each of these, when the time for division comes, the chromosomes conjugate just as they do in the primary spermatocytes. Also, as the result of this division the number of the chromosomes becomes halved in each of the two daughter-cells. The latter, however, are of very

¹ McMurrich, *The Development of the Human Body*, p. 19.

² Gray's *Anatomy*, p. 44.

unequal size. One of them, by retaining nearly the whole of the protoplasmic contents of the mother-cell, becomes much the larger of the two, whilst the other, the so-called *First Polar Body*, appears at its side like a minute bud. After this the larger cell again divides, throwing off a *Second Polar Body*, but this time without any further reduction in the number of the chromosomes. As a rule, the first polar body also divides, producing two still smaller bodies.

It will be seen, therefore, from the above account that the primary oocyte resembles the primary spermatocyte, in that it gives rise to four cells, each of which contains half the normal number of chromosomes. It differs from it, however, in that three of these cells, namely, the polar bodies, remain extremely small, whilst the fourth, rich in protoplasm and very much larger than the rest, is the only one which actually becomes an ovum. Moreover, the latter has not to pass through any further change corresponding to that by which a spermatid is converted into a spermatozoon.

In shape the ovum is nearly, if not quite, spherical, and when ready for fertilisation often exceeds the spermatozoon in size by several thousands of times. This is due in part to the fact that, as already stated, it has appropriated to itself nearly all the protoplasm of the primary oocyte. Besides this, it has grown enormously, and in many cases has become stocked with a greater or less amount of yolk—that is, with a large number of yolk-granules.

It remains to add that the various processes now described, by which both sets of reproductive cells are gradually differentiated from all the other cells in the body, constitute what is known as *Maturation*.

As above mentioned, the entry into the ovum of a single spermatozoon is quite sufficient to effect fertilisation. Indeed, in most cases ¹ means are taken to prevent the entry of any more of them, by the ovum immediately surrounding itself with a practically impervious membrane. At about this stage, if it has not done so already, the spermatozoon casts off its tail, which being of no further use quickly disintegrates and is soon lost to view. The remaining portion,

¹ The common newt is an exception to the rule.

consisting of the head and the middle piece, now advances towards the centre of the ovum, having previously rotated through some 180 degrees, with the result that the middle piece goes first. Close to the latter, and probably originating from it, a centrosome appears, and shoots out a number of rays in various directions through the surrounding protoplasm. Meanwhile, the nucleus of the ovum, which in many instances has not till now undergone its final divisions, retreats towards the circumference of the cell, where it rapidly extrudes one after the other the first and second polar bodies. Having got rid of them and also of its own centrosomes, it retraces its path, until presently the two nuclei, the male and the female, coming within the range of their mutual attraction, slightly alter their course and begin to move towards each other. At the same time their nuclear membranes disappear, just as in ordinary cell-division, and the male centrosome—the one, that is, which is supposed to be derived from the middle-piece—divides into two. Between these two, as they separate, an achromatic spindle is gradually formed, and in the plane at right angles to the line joining them and passing through its middle point, the two sets of chromosomes begin to arrange themselves. They do not, however, join up to form a continuous spireme thread, but without any further ado each splits longitudinally into two halves. Shortly afterwards, and again just as in ordinary cell-division, all the different halves thus produced draw asunder, so as to constitute the nuclei of the two new daughter-cells. In this way the great developmental process, as described in the three preceding chapters, is at last started on its course.

There are two points to be specially noted here. The first is, that, whereas the ovum contributes to the germ-cell nearly the whole of the extra-nuclear protoplasm, including, of course, any yolk-granules which may happen to be present in it, the spermatozoon contributes the centrosome, which, as giving rise to the achromatic spindle, is the organ by which directly the first cell-division, and indirectly all the subsequent cell-divisions, in the embryo are brought about. The second point is, that the ovum

and the spermatozoon each contribute an equal number of chromosomes to the germ-cell, and by so doing bring the total up to the full number for the particular species. This, of course, is because the number contributed by each is exactly half the full number,¹ the necessary reduction having previously occurred during maturation. If it were not for this reduction, clearly there would be a doubling in the number of the chromosomes at each succeeding generation.

Again, not only in the germ-cell have half the chromosomes been derived from the father and half from the mother, but it follows from what has been said already that this must be true also of all the cells which ultimately go to make up the body of the new individual. And that this is really the case has been definitely proved by the following experiment.² The ova of a particular fish—a *Fundulus*—were fertilised with spermatozoa obtained from another and very nearly allied fish—a *Menidia*; in which two fishes, however, the chromosomes differed from one another considerably both in size and general appearance. Now in the hybrid which was the result of this intercrossing the microscope showed that in every cell of its body half the chromosomes were of one kind and half of the other.

Let us now represent the chromosomes in each of the nuclei of a given organism by some such series of letters as we employed just now, viz. by $A_1, A_2; B_1, B_2; C_1, C_2; \dots$ etc., and let the numbers thus affixed to them be such that $A_1, B_1, C_1, \dots$ etc., denote those which have been derived from the father, and $A_2, B_2, C_2, \dots$ etc., those which have been derived from the mother. Having agreed on this notation, it is important to remember that when afterwards the new reproductive cells are being formed, it is always an A_1 which conjugates with an A_2 , a B_1 which conjugates with a B_2 , and so on; in other words, all conjugations take place between paternal chromosomes on the one hand and maternal chromosomes on the other, each of them invariably conjugating with its own mate.

Again, we have already seen that, as the result of these

¹ The exceptions to this rule will be dealt with presently.

² T. H. Morgan, *Mechanism of Mendelian Inheritance*, pp. 120, 121.

conjugations and of the many different ways in which afterwards the chromosomes may become grouped together, the reproductive cells may be of as many different kinds. Thus in the fruit-fly there may be sixteen such different kinds, and this holds good of both the spermatozoa and the ova. Hence when these unite, the total number of the possible combinations will be 16×16 —that is, the total number of the slightly different individuals possible among the offspring of a single couple will be 256. And in the human species with its 48 chromosomes, and their many millions of possible combinations, this number will mount up to nearly 300 billions.

There is one important conclusion to which the facts already described, and others still to be mentioned, would appear to lead up. It is that the nucleus in the germ-cell is probably connected in some very intimate way with the transmission of the hereditary characters. It is not the germ-cell as a whole, but the nucleus which exercises the determining influence on what the new individual, the future organism, shall be like. In proof of this the following points are to be noted :—

1. If the reproductive cells as a whole, and not their respective nuclei, had principally to do with the transmission of the hereditary characters, then, seeing that the ovum is often many hundreds and even thousands of times larger than the spermatozoon,¹ we should naturally expect the maternal characters to reappear in the offspring to an altogether preponderating extent as compared with the paternal ones. But inasmuch as on the average these two sets of characters are about equally transmitted, the inference would seem to be that this is effected by the nuclei, which are approximately of the same size.

2. Moreover, as again agreeing with the practically equal transmission of the paternal and maternal characters, we have the fact that in nearly every case the spermatozoon and the ovum each contribute to the germ-cell the same number of chromosomes. The significance of this fact will at once be obvious.

¹ J. A. Thomson, *Heredity*, p. 27.

3. It must be clear, too, from the description given above that the mere entry of the spermatozoon into the ovum is not the main event in connection with fertilisation. The main event is the union of the male and female nuclei and the consequent intermingling of their respective contents.

4. Although the head of the spermatozoon apparently consists of nuclear material only, it is quite true that the tail is derived from the *Cytoplasm* of the spermatid—that is, from the general protoplasm surrounding the nucleus. It has been argued, therefore, that the tail may at least have some share in determining what the offspring shall be like. But if so, what are we to say of those cases in which the tail never gains entrance into the ovum at all, but remains outside?

5. Further, the notion that any cytoplasm brought in by the spermatozoon exercises an hereditary influence, has apparently been negated by a remarkable experiment performed by Herbst.¹ He put the unfertilised ova of a particular species of sea-urchin into some salt water to which a small quantity of valerianic acid had been added. This caused the female nucleus to divide parthenogenetically—without being stimulated, that is, by the entrance of a spermatozoon. After the nucleus had undergone this its first division, but *before the cell as a whole had divided*, a spermatozoon belonging to another species was introduced, which presently united itself to one of the newly formed female nuclei. Consequently, when shortly afterwards the cell itself divided, one of the daughter-cells contained both paternal and maternal chromosomes, whereas the other contained maternal ones only. For result the embryo on one side of its body was found to be hybrid in character—presenting, that is, features belonging to both parents—while on the other side it presented features belonging to the mother only. Now if the small amount of cytoplasm introduced by the spermatozoon had brought with it any influences of an hereditary kind, we should have expected them to have affected the entire cell, seeing that the latter had not yet divided at the time of the spermatozoon's

¹ T. H. Morgan, *Heredity and Sex*, diagram, p. 61.

entrance. And hence later on we should have expected the developing embryo to have exhibited paternal features on both sides of its body. Inasmuch, however, as it did not do so, the inference would seem to be that, at all events among sea-urchins, the chromosomes, and the chromosomes alone, have to do with the transmission of the hereditary characters.

6. There is just one other argument to which I wish to refer. Contrary to what is usually found, there are certain cases in which the number of the chromosomes in the male is odd instead of even, being exactly one less than the number in the female. Let us take for example the insect *Protenor Belfragii*.¹ In the female there are 14 chromosomes in each of its ordinary cells—that is, there are 7 pairs of them, which I will denote by the symbols A^* , A^* ; B, B; C, C; . . . G, G. For a special reason which will appear presently I have affixed a small $\times$ to each of the A chromosomes, and I may remark at the same time that under the microscope these A^* chromosomes are clearly distinguishable from the other 12 by their larger size. In maturation the above pairs, of course, separate in the usual manner, so that each ovum comes to have just 7 chromosomes, namely, A^* , B, C, . . . G. The male insect, on the other hand, has only 13 chromosomes in each of its ordinary cells, namely, A^* , —; B, B; C, C; . . . G, G, one of the A^* 's being absent. Hence in maturation the single A^* has no mate to conjugate with, and when the other chromosomes are drawing apart to form the two daughter-groups, it can only throw in its lot with one of them. Thus two different kinds of spermatozoa are produced, one with 7 chromosomes, namely, A^* , —, B, C, . . . G, and the other with only 6, namely, B, C, . . . G. And this leads to very curious consequences. For if an ovum with its 7 chromosomes happens to be fertilised by a spermatozoon which has only 6, there will be only one A^* in the germ-cell, and the final result will accordingly be a male; whereas if another ovum with its 7 chromosomes happens to be fertilised by a spermatozoon which likewise has 7, there will be two A^* 's

¹ T. H. Morgan, *Heredity and Sex*, pp. 40-44.

in the germ-cell, and the final result will accordingly be a female.

From this we learn that, whatever other determining influences the chromosomes may or may not exert, they at least in the case of this particular insect exert an influence as regards sex. And this determining influence is lodged apparently not in the chromosomes as a whole, but in those only which we have agreed to label A^* . Hence they have received the name of *Sex-chromosomes*, and it is for this reason that I have affixed to them a special symbol.

Now the little insect *Protenor Belfragii* does not stand alone in this respect. There are many other organisms in which it has been found possible to identify the sex-chromosomes; and this makes the presumption very strong that whenever in the male of any species the number of the chromosomes in each of its cells is one less than the number of them in the female, we are face to face with precisely the same phenomenon, although we may not be able under the microscope to detect any differences among the chromosomes. Not only so, but even in those cases in which the number of the chromosomes happens to be the same in both sexes, there seems evidence to show that, if in the female we represent the constitution of the nucleus in each of its body cells by the formula A^* , A^* ; B, B; C, C; . . . etc., then we ought to represent it in the male by the formula A^* , A; B, B; C, C; . . . etc. But this means that in maturation there will again be produced two different kinds of spermatozoa, namely, those containing an A^* and those containing merely an A, and that the sex of every individual will depend as before on whether in the act of fertilisation one or two A^* 's happen to be brought together in the germ-cell. We thus obtain additional proof of the general proposition, that the chromosomes in the germ-cell are in some most extraordinary manner concerned in determining the nature of the individual which will eventually be developed from it. Also, it would seem that particular chromosomes have to do with the handing on of particular characteristics.

CHAPTER XVIII

IN SEARCH OF AN EXPLANATION (*continued*)

WEISMANNISM

THE difficulty of understanding by what exact means the various hereditary characters are passed on from one generation to the next would be greatly lessened if, like the Protozoa, all animals consisted of a single cell. For in the Protozoa and in the Protophyta, which correspond to them among plants, the reproductive process scarcely seems to call for an explanation, seeing that in most cases when it occurs, the entire substance of the parent-cell is parcelled out between the two daughter-cells. It is only natural, therefore, that they should closely resemble the parent-cell. It is otherwise, however, with organisms consisting of many thousands and perhaps millions of cells which, instead of being all alike, have become differentiated in a great variety of ways, and have been built up into a number of extremely complicated parts. Here the problem becomes a very real one, for we have to explain why, when one of these multicellular organisms throws off what after all is only a single cell, that cell should be able, after fertilisation by another practically similar cell, to develop into an individual of the same complicated structure as its parents.

We have seen that Darwin in his theory of Pangenesis endeavoured to solve this problem by supposing that in every reproductive cell there existed a vast array of exceedingly small particles, to which he gave the name of gemmules, and which, as drawn from, and therefore representing, all the cells in the body of the parent, were somehow capable of giving origin to precisely similar sets of cells in the body of the offspring. One of the chief objections to this theory was, as I pointed out, its failure to explain how any such

assemblage of entirely *disconnected particles* could of itself give rise to an individual exhibiting all that elaborate and very definite arrangement of parts which distinguishes one of the higher animals or plants. It has appeared, therefore, to many that, in order to account for this, there must be present in the germ-cell some sort of an organised structure answering to the organised structure which will afterwards be evolved from it, though the former need by no means be conceived of as a miniature representation of the latter, as was done by the early preformationists.

Now Weismann's famous theory, which we are to consider in the present chapter, was based upon just such an idea. In place of Darwin's gemmules, but in a manner corresponding to them, he assumed the existence in the germ-cell of an enormous number of minute entities, to which he gave the name of *Determinants*, because each was regarded by him as the determining cause of some particular cell, or group of cells, in the future individual. These determinants, moreover, on the strength of the arguments explained at the end of the previous chapter, were conceived of as situated in the chromosomes, but instead of forming a merely loose array, they were supposed to be built up into a number of units having a very definite structure, to which he gave the name of *Ids*. Of these last there were several in each chromosome, and they were probably identical—so he conjectured—with the chromatin granules microscopically observable in each chromosome, as already explained in Chapter XIV.¹ An id was further supposed to contain a complete set of determinants, so that if we were to denote the various parts of the body by the symbols *A, B, C . . .*, and the determinants which gave rise to them by the corresponding symbols *a, b, c . . .*, then there would be just such a series of the latter in every id.

The above statement, however, requires considerable modification; for, according to Weismann, the majority of the ids break up during development into fragments of ever simpler constitution, and these fragments become distributed

¹ Weismann, *The Germ Plasm*, p. 67; *The Evolution Theory*, vol. i, pp. 349, 354.

among different classes of cells. Thus if, following the above notation, we were to represent the determinants entering into the composition of the germ-cell by the series a to z , then sooner or later there would come a time when a cell having this constitution would divide into two, in one of which perhaps there would only be the determinants a to k , whilst the rest of the determinants, l to z , would have passed into the corresponding sister-cell. But disintegration of this kind having once begun would not stop. The a to k cell might possibly for a time give rise by its subdivisions to cells of the same constitution as itself, but before long another rupture would occur in their ids, and we should have cells arising now, in the nuclei of some of which there would only be present perhaps the determinants a to f , while in others there would only be present the determinants g to k . We need only imagine, therefore, this process to be carried to completion, and we should at last get cells, in each of which the determinants would be of one kind only, some cells, for example, containing only a 's, others only b 's, and so forth. But at this stage, according to Weismann, the determinants would themselves begin to break up into particles still more minute—his so-called *Biophors*—and of these there would necessarily be as many different kinds, taking the body as a whole, as there had been different kinds of determinants originally present in the ids of the germ-cell. Now it was to these biophors that Weismann attributed the final differentiation of the tissues. They were supposed, on account of their extreme minuteness, to be able to pass with ease through the delicate membranes which invest the nuclei, and having got out into the general protoplasm of the cells to transform them into cartilage cells, bone cells, nerve cells or muscle cells, as the case might be, the differences being due, of course, to the different kinds of determinants, by the breaking up of which the biophors had been produced. According to this theory, then, the germ-cell contains, in the form of a number of very definite architectural structures, viz. the ids, all the potentialities of the various cells, tissues and organs which will ultimately be produced from it;

but as development proceeds and the ids go on disintegrating, these potentialities will become increasingly parcelled out among different classes of cells, till at the end of the process each class will be only capable of taking on a particular character and of discharging a particular function.

Another most essential point in connection with Weismann's theory was that, although in the course of development the vast majority of the ids were continually breaking up in the manner described, there were always within the body a number of cells, genealogically derived like the rest from the original germ-cell, in which no such disintegrating process ever took place. These were the cells which collectively formed the germ-track and which gave rise in time to the reproductive cells, viz. the spermatozoa and the ova. Seeing, then, that along this track all the ids in every cell were equipped with complete sets of determinants, it followed that the same held true of the reproductive cells derived from them, and that each of the latter was possessed, therefore, of all that was necessary for the production of a new individual.¹ In this way Weismann sought to account for the transmission from one generation to the next of the various hereditary characters, and to account more especially for the alleged fact, upon which he was particularly strong, that acquired characters are not transmitted, and still less any which are of the nature of a mutilation. Thus in the instance previously quoted, the reason why the cutting off of a mouse's tail did not prevent tails from being developed in its offspring, was that such treatment did not in the least affect the cells strewn, so to speak, along the germ-track, and that, therefore, none of the ids contained in these cells were deprived thereby of their tail-producing determinants. And certainly in this respect the theory got rid of a serious difficulty with which, as we have seen, the theory of Pangenesis was encumbered. It also got rid of the other difficulty, viz. that of understanding how it was possible for the gemmules thrown off by all the different cells of

¹ Needing only in most cases the stimulus which was supplied by the union of the sexes.

the body infallibly to find their way, not one missing, into the spermatozoa and ova.

Before offering any remarks of a critical kind on this highly ingenious theory, it is only right to point out that in the embryological development of many animals there is much which at first sight appears to give it countenance. Take, for example, the case of the round worm of the horse, *Ascaris megalocephala*. The fertilised ovum by its very first division gives rise to a pair of daughter-cells which, if we ignore all other considerations, would almost compel us to regard them as differing from each other in their inner constitution. Thus from one of these most of the ectodermal parts of the body are derived but none of the other parts, whilst from the other cell are derived, not only the endoderm and the mesoderm and the rest of the ectoderm, but all the cells of the germ-track, together with those which form the *Stomodæum*—that is to say, the anterior portion of the food canal. The nature of the process will perhaps best be understood by means of the accompanying diagram (fig. 31).¹

It is difficult, therefore, on the face of it to avoid the conclusion that in the development of the round worm of the horse there is something continually happening which appears to lend support to Weismann's theory. Step by step, and in quite orderly fashion, there would *seem* to be an apportioning out to the various sets of cells of their distinctive potentialities—potentialities which, to begin with, were all locked up in the germ-cell. Notice that in the diagram a cross has been placed in every cell in which, when it divides, there must take place *according to this theory* a certain amount of disintegration amongst its ids.

Again, there are the *Ctenophors*, which are little balloon-shaped marine animals of a glassy appearance less than an inch long and often provided with a couple of tentacles. Their outer surfaces are marked by 8 meridional bands, each consisting of a row of minute, comb-like structures, which by their vibrations enable the little creatures

¹ Founded on description given in Jenkinson's *Experimental Embryology*, p. 255.

to swim about. Hence the name of Ctenophors or comb-bearers. If, now, the two daughter-cells into which the

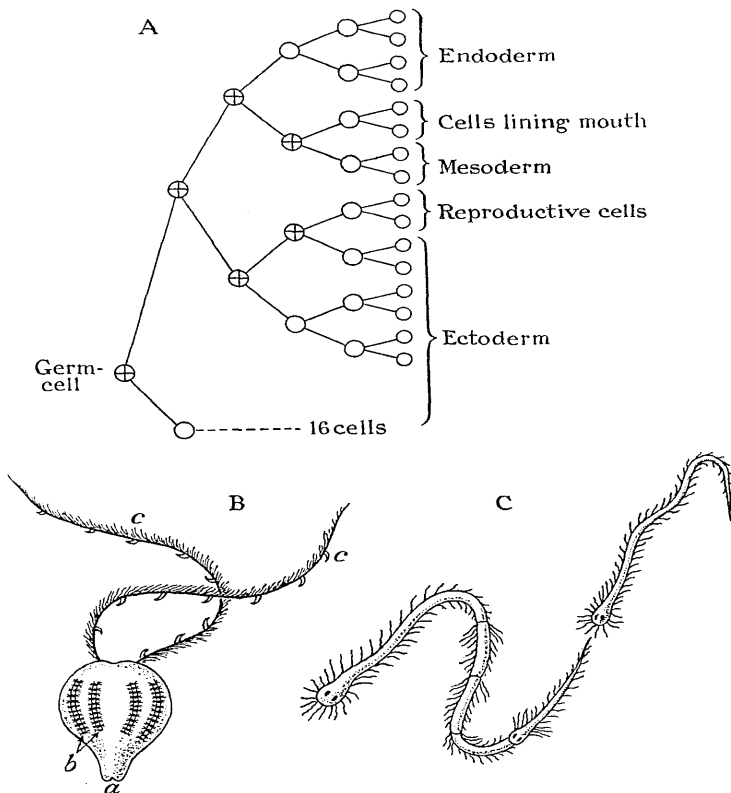


FIG. 31.—A. Diagram illustrating the first few generations of cells in the development of the Round Worm of the Horse, showing the way in which the ectoderm, mesoderm and endoderm originate.
B. A Ctenophor. *a*, Mouth end; *b, b*, Comb-like structures; *c, c*, Tentacles.
C. A Myrianida, dividing.

ovum first divides are put into water and shaken apart, each will develop into a half embryo with 4 meridional

bands. Again, if after the second division the 4 cells are shaken apart, each will develop into a quarter embryo with 2 meridional bands. A similar result will follow at the 8-celled stage. At the next stage, however, something new occurs, for the cells, instead of being all alike, are seen to be of two different kinds, viz. 8 larger ones called *Macromeres*, and 8 smaller ones called *Micromeres*. It is now found that if, as the result of shaking, these 16-celled embryos get divided up in different ways, the number of the meridional bands, which will eventually appear in any of the separated portions, will depend on the number of the micromeres it contained. Thus, if a separated portion contained, say, 7 macromeres and 2 micromeres, only 2 bands will appear, whereas if it had contained 2 macromeres and 5 micromeres, 5 bands would have appeared. This, therefore, would seem to show that, whatever the cause may be which leads to the formation of a band, it has somehow at the 16-celled stage become located in one of the 8 micromeres.¹ And so once more support would seem to be given to Weismann's disintegration theory, although, as we shall see presently, there are other things which point to quite a different conclusion.

In the remainder of this chapter I shall endeavour to prove two important propositions. The first will be that, granting for the sake of argument that Weismann is correct as to the existence of his ids, his determinants and his biophors, and that they all play their parts in the manner he supposed, it is a theory which standing alone is wholly insufficient to account for what actually takes place in the course of individual development. In a word, it leaves the great mystery still unsolved. And my second proposition will be that in one of his fundamental assumptions Weismann was undoubtedly wrong.

I. In support of the first of these propositions the following reasons may be adduced:—

1. If it be true that the ids during development are continually breaking up into smaller and still smaller groups of determinants, Weismann leaves us entirely in the dark

¹ Jenkinson, *Experimental Embryology*, pp. 203-212.

as to what it is which causes these disintegrations to occur in the orderly manner they do. Apart from such orderly occurrence the different organs of the body would never come to be of their right sizes and shapes, and to occupy their right relative positions. It must constantly happen during development that certain groups of determinants, which have hitherto constituted a structural whole, are compelled, in accordance with some very definite rule and at the exact right moment, to part company with one another and by so doing to form nuclei qualitatively unlike. But what is there in the nature of the *ids* to insure the strict observance of this rule, for plainly if not adhered to, the result would be utter confusion and the production of almost any number of monstrous forms? Weismann casts no light whatever on this important question.

2. Again, at each of these disintegrating divisions not only must the determinants part company with one another in a certain definite way, but the two sets of cells arising from their subsequent divisions must somehow be guided aright to their final destinations in the fully grown organism. But how is this end secured, and what directs the cells in their subsequent movements? Consider, for example, what on this theory must happen in the case of the retina. The retina, as we have seen (Chapter X), with its many layers of cells, including, of course, the layer of the rods and cones, is one of the most highly specialised structures in the body. It is absolutely unique, being the only one which responds to those infinitesimally minute vibrations of the ether which we call light. This being so, its determinants must be of an equally distinctive kind, quite different from all the rest. But these determinants have somehow to be conveyed from their original seat in the germ-cell to a couple of small areas, one at the back of each eye. But how, in virtue of any supposed architectural arrangement of them within the *id*, is this thing accomplished? What guides them in their course, so that first they get lodged on the dorsal side of the body in certain cells of the ectoderm which are folded in to form the neural tube, thence are passed along to certain other cells situated

in the fore-brain, and lastly find their way into those particular portions of the optic vesicles which are presently invaginated to form the optic cups? Questions of this kind are asked, not with a view to discrediting the idea that certain minute bodies answering in some sort to Weismann's determinants may have a real existence, but with a view to discrediting the idea, as before said, that *they can in themselves* furnish a sufficient explanation of what takes place. Or once more, consider the extremely complicated series of events, all depending on these supposed disintegrating processes, which must gradually lead up to the formation of any one of our bones. In this case we have cartilage cells, bone-producing cells and bone-destroying cells, all at different stages playing their parts, and each kind bringing with it to the task its own special set of determinants. But what secures the co-operation of these multitudinous little workers, so that for final result we have the highly finished, perfectly shaped bone with its elaborate internal system of Haversian canals, etc., and the whole supplied with all that is necessary in the way of blood-vessels and nerves?

3. Further, the organism as finally developed is by no means a structure consisting of a number of immovable parts deftly put together once for all; it is a structure which is incessantly undergoing changes of a physiological kind, and which apart from such changes would immediately begin to fall to pieces and so cease to be. Its very life depends upon, and indeed consists of, these changes. But in what way, if at all, are we to conceive of them as being predetermined by anything of a material nature existing within the germ-cell? If the id is merely a statical arrangement of a number of material particles, how can it of itself give rise to such elaborate and closely interrelated functions, as for instance digestion, respiration and the circulation of the blood? Nor is the difficulty which one feels here appreciably lessened, if we imagine certain actions and interactions to be going on amongst the determinants forming the ids, because if such there be, they must necessarily be wholly different in kind from the functions just mentioned, and cannot in fact bear the smallest resemblance to them.

The truth is, Weismann's theory does not even attempt to account for the origin of function—and the same may be said of practically all other theories of a mechanistic kind—although, as compared with structure, function stands much more in need of explanation.

In this connection let us consider, for example, the extreme difficulty of conceiving how any mere arrangement of determinants within the id can possibly explain the fact that in mammals at the time of birth there should occur that extraordinary change in the circulation of the blood which was described in Chapter XVI. It will be remembered that previous to birth the blood is continually being sent to the placenta to obtain food and oxygen, inasmuch as the proper organs of digestion and respiration are still undergoing development, and apart from that are, as at present situated, incapable of exercising their functions. But that the blood may circulate under these peculiar prenatal conditions, not only must there be a special set of arteries and veins to convey it to and fro between the placenta and the growing child, but there must be within the body of the child (*a*) a passage temporarily opened up between the two auricles of the heart, viz. the so-called foramen ovale; (*b*) a flap or ridge inside the right auricle to enable two distinct streams of blood to pass through it without any appreciable intermingling; and (*c*) a channel of communication, also of a temporary character and known as the ductus arteriosus, between the right ventricle and the descending portion of the aorta.

Now granting for the moment that all these special contrivances can be accounted for as the result of the architectural structure of the ids within the germ-cell, it seems almost incredible that the remarkable changes which take place at birth should also be accounted for in the same way—the changes, namely, which lead to the closing up of the foramen ovale, the conversion of the ductus arteriosus into a solid cord, and the forcing of the blood in consequence to pursue an entirely different course.

4. Lastly, although Weismann's theory is based upon the fact, which we may consider as proved, that the chromo-

somes are in some very intimate manner concerned in the transmission of the hereditary characters, it offers no explanation whatever as to why there should be that peculiar halving of their number during maturation, or as to why they should conjugate together in pairs in the remarkable way they do.

II. I have next to show that Weismann in one of his most fundamental assumptions was entirely wrong—that assumption upon which one might almost say his entire system was based. To be more specific, there are certain facts now to be described which point strongly to the conclusion that no such disintegrating processes take place as he supposed, but that in all the cells of the body, however much they may differ among themselves in other ways, the chromatin material is identically constituted.

1. First, there are those many cases in which a lost part is afterwards regenerated—that is to say, formed entirely *de novo*. I have already referred to some of these in Chapter II, as when, for instance, a lobster, having had one of its claws cut off, immediately proceeds to grow another, or when a newt performs a similar feat after the removal of the lens from one of its eyes. A newt, too, can even regenerate a lost leg. Weismann himself says of it: “If its forelimb is cut off between the shoulder and elbow, not only does the lost portion of the humerus form afresh, but the radius and the ulna and all the bones of the wrist and hand are regenerated accurately, even as regards the number of the segments.” And he adds—and it is a somewhat remarkable admission on his part: “It seems hardly possible that so complex a structure could be produced merely by the co-operation of proliferating cells, and it might be supposed that an invisible power—a *spiritus rector* or a *vis formativa*—must be present to direct the mode of increase and arrangement.”¹ It is not surprising, however, that, holding the philosophical views which he did, he should have hastened at once to repudiate such a notion. In order to explain what happened in the above and in all similar cases, he supposed that, although during development the vast majority of the cells were continually breaking

¹ Weismann, *The Germ Plasm*, p. 100.

up into smaller and still smaller fragments, there were others in every part of the body which only did so to a more or less limited extent. These last were ready, therefore, in case of any emergency, like the loss of a portion of a newt's leg, to supply the determinants necessary for its reconstruction. But this was a device so entirely out of harmony with the rest of Weismann's system, and so obviously foisted into it for the sake of getting rid of an awkward difficulty, that one can scarcely regard it in any other light than as a subterfuge. Besides, the facts of regeneration can so much more easily be explained even on the mechanistic hypothesis, by supposing that in the nucleus of every cell in the body—and not only in that of the germ-cell—the full complement of determinants is present.

2. We will take next the case of the marine worm *Myrianida*, one of the annelids. After maturity has been reached certain constrictions begin to make their appearance at various distances along its body, which lead to its breaking up automatically into a number of pieces, each of which becomes a separate individual, and each of which provides itself at its anterior end with a pair of eyes. But these new pairs of eyes are formed at places where before there were no eyes, and, therefore, we must assume that at these places there had all along been determinants for producing them, though hitherto they had remained inactive. Again, there is the allied species *Lumbriculus*, which, when cut in two almost anywhere along its length, becomes two worms, by the anterior portion regenerating a new tail and the posterior portion regenerating a new head¹—a proceeding which can only be accounted for on the supposition that both head-forming and tail-forming determinants must exist in practically every part of the animal's body, although in the vast majority of cases they remain inoperative.

3. Among plants it is well known that Begonias can be propagated from small pieces of leaf. In other words, a Begonia leaf under suitable conditions can give rise to a complete plant. This being so, its cells must contain not only leaf-determinants, but all those which are necessary

¹ Weismann, *The Germ Plasm*, pp. 126, 146.

for the production of roots, stems, flowers, fruit and seeds.

4. To return to animals. It has been shown in many instances that when the germ-cell undergoes its first division, the plane separating the two daughter-cells corresponds to the sagittal plane of the future animal, or, what is practically the same thing, the two daughter-cells give rise by their subsequent divisions to the right and the left sides of the body respectively. Now it is often possible, as we have already seen in the case of the Ctenophors, to separate these two cells completely and to watch their further development. But the result is not always the same. In some animals, like the Ctenophors, each cell develops into a *half* embryo, suggesting the idea that there has been a separation of the determinants such as Weismann supposed, whereas in other animals each cell develops into a *whole* embryo, suggesting the idea that there has been no such separation. The curious thing is, however, that in the frog either of the above two results may follow, and that *which it will be depends on the position of the cell with respect to gravity*—as to whether, that is, it is placed in the upright or in the inverted position.¹ From this we conclude that each of the two daughter-cells must certainly contain the full complement of determinants, and that in those cases in which only half embryos are formed, it is not because the determinants for the other halves are wanting, but because for some reason or another they remain inactive. And a similar explanation can be given of the half and quarter embryos, etc., produced in the previously described experiments on Ctenophors.

5. Once more, a number of experiments have been performed on the fertilised eggs of certain animals after they have passed through their first few divisions, in which experiments they have been subjected to pressure between two parallel plates of glass. It has thus been found possible to alter completely the positions of the cells in their relations to one another, with the remarkable result that the embryo, in spite of such exceedingly drastic treatment, has nevertheless proceeded to develop normally. But this means

¹ Jenkinson, *Experimental Embryology*, pp. 170, 171.

that certain cells, which otherwise would have produced a particular organ, have produced an altogether different one, proving clearly that the ultimate fate of these cells did not depend on their nuclei containing this or that other peculiar combination of determinants, but depended rather on the new positions which the cells were forced to take up in relation to one another and to the other parts of the body in consequence of the pressure applied to them.

The above facts, then, when duly considered, are wholly irreconcilable with Weismann's theory, so far at least as his speculations about the disintegration of the ids are concerned.¹ More than that, the very existence of the ids is rendered doubtful. On the other hand, the facts are by no means irreconcilable with the general idea that determinants, or at least certain entities closely analogous to them, may have a real existence, and, if so, are almost certainly situated in the chromosomes.

There is yet another important respect in which Weismann's theory requires modification. He supposes, as we have seen, not only that the chromosomes in the nucleus of the germ-cell contain a very large number of ids, but that every id is composed of a complete set of determinants. But there are certain facts which tend to show that in the chromosomes of the germ-cell, even when taken all together, there are only two complete sets of determinants, and that these are lodged in the paternal and maternal chromosomes respectively. One of these sets has been derived, of course, from the spermatozoon and the other from the ovum. They may be represented, therefore, by the two series, $a_1, b_1, c_1 \dots$ and $a_2, b_2, c_2 \dots$.

That the maternal chromosomes when taken all together contain *at least* one complete set of determinants is proved by the fact that in certain insects, such as ants, bees and wasps, the males are all produced parthenogenetically—that is, are developed from ova which have never been fertilised. But seeing that an ovum contains only half the normal

¹ "The facts which experiment has brought out show conclusively that nuclear division is never a qualitative process."—Jenkinson, *Experimental Embryology*, p. 280.

number of chromosomes, and therefore only that series of determinants which we have just denoted by the series $a_2, b_2, c_2 \dots$, it is plain that this series must contain a complete set—that is to say, all that are necessary for giving rise to a perfect individual.

But a perfect individual has also been obtained by a very curious experiment, in which the nucleus of an ovum was carefully extracted and a spermatozoon inserted in its place, clearly showing that the series of determinants which we have denoted by $a_1, b_1, c_1 \dots$ must similarly contain a complete set.

But does each of these series contain more than one complete set? This question seems to have been answered in the negative by another equally curious experiment performed by Boveri on the ova of the sea-urchin;¹ but not only would it take too long to describe it, but the argument based upon it might prove perhaps a little difficult to follow.

To sum up what has been said in this and in the preceding chapter about the chromosomes, the main facts and conclusions arrived at regarding them are as follows:—

1. The nucleus in every cell of the body (with the exception of the reproductive cells) contains exactly the same number of chromosomes, this being due to the fact that at every cell-division the chromosomes split into two, half of the total number thus produced going into each of the two new daughter-cells.

2. The number of the chromosomes is also the same for all individuals belonging to the same species, except that sometimes among the males the number is one less.

3. There is good reason to believe that the chromosomes are by far the most important, if not the exclusive, instruments by which in some inscrutable manner the various hereditary characters are passed on from one generation to the next.

4. Also, there is good reason to believe that the chromosomes in each cell, as well as the chromatin-granules composing them, differ amongst themselves qualitatively, their constituent elements, whether we call them determinants or

¹ T. H. Morgan, *Heredity and Sex*, pp. 55-58.

bestow on them some other name, having each to do with the transmission of certain hereditary characters.

5. These constituent elements are practically the same in all the cells of the body, and are the same as those which were originally present in the germ-cell. During embryonic development no such disintegrating process sets in as Weismann imagined.

6. The chromosomes in every cell exist in pairs, one out of each pair having been derived from the father and the other from the mother, so that half the total number are of paternal, and the other half of maternal, origin.

7. In the formation of the reproductive cells—the spermatozoa and the ova—a stage is reached when the members of each pair of chromosomes conjugate with each other and afterwards draw apart without dividing. The result is that every reproductive cell contains only half the normal number of chromosomes. In some instances, however, certain of the spermatozoa come to possess just one chromosome less.

8. To this half number each conjugating pair contributes one chromosome, but inasmuch as the members constituting each pair are always slightly dissimilar, one being of paternal and the other of maternal origin, a considerable number of combinations of chromosomes, qualitatively differing from one another, are possible in the reproductive cells. Thus with 4 pairs of chromosomes there may be 2^4 or 16 combinations, while with 15 pairs of chromosomes there may be 2^{15} or 32,768 combinations.

9. As the result of the fertilising process—the coming together, that is, of a spermatozoon and an ovum—the chromosomes in the germ-cell are necessarily restored to their full number.

10. Finally, there is evidence to show that in the germ-cell the paternal set of chromosomes contain all the material elements (determinants) required for the production of a new individual, but no more than are required, and that the same is true of the maternal set. Mendelism, as will be seen in the next chapter, confirms this conclusion.

CHAPTER XIX

IN SEARCH OF AN EXPLANATION (*continued*)

MENDELISM AND THE FACTORIAL HYPOTHESIS

WE have now to consider an altogether new class of facts which, as will appear presently, have a very important bearing on the subject before us.

Mendelism takes its name from Gregor Mendel, who was born in the year 1822, and who in 1843 entered the monastery of Bränn, some seventy miles north of Vienna, and was soon afterwards ordained priest. In 1865 he read a paper before the Natural History Society of Bränn, in which he described certain remarkable results which he had obtained by the intercrossing of different varieties of the common pea—*Pisum sativum*. Little notice was taken of his paper at the time. In fact, it remained in obscurity till some sixteen years after his death, when just about the beginning of the present century it was once more brought to light and recognised at its true value as one of the most important contributions to our present-day knowledge. It is true that Mendel's own experiments covered but a limited field, but they were enough to furnish a clue which in recent years has been most diligently followed out, and which has led to the creation of a quite new and distinct branch of biological science. Into its many complex ramifications there is no need for me to go. It will be enough if, for the general purpose which I have in view, I briefly explain its leading principles. We will take first Mendel's two great Laws—the Law of *Germinal Segregation* and the Law of *Independent Assortment*.

I. *The Law of Germinal Segregation* will best perhaps be understood if we begin by considering the case of the garden

plant, *Mirabilis jalapa*, of which there are two well-known varieties bearing red and white flowers respectively. If the *Pollen* (the male element) of one of these is applied to the *Pistil* (the female organ) of the other, seeds are produced which when sown give rise to plants, the flowers of which are pink—that is, of a tint intermediate between red and white. In this, of course, there is nothing in the least surprising; the surprising thing is what happens when these pink flowers are afterwards self-fertilised or crossed with one another and a sufficient number of the seeds so obtained are sown. The plants which come up are of three different kinds—a quarter of them bearing red flowers, a quarter of them bearing white flowers and the two other quarters pink ones. We may tabulate these results as follows, using the symbols F_1 and F_2 to denote respectively what are usually described as the first and second filial generations.

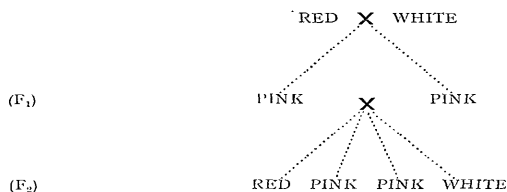


FIG. 32.

If, now, the reds of the F_2 generation are self-fertilised or crossed with one another, only reds will be obtained; and if these last in their turn are treated in the same way, the result will again be only reds, and so on through any number of subsequent generations. From this we conclude that the F_2 reds are *pure* reds, and that the white factor, whatever it may be, has been completely eliminated in them. Similar experiments with the whites of the F_2 generation lead to the similar conclusion that they are *pure* whites—that is, that in them the red factor has been completely eliminated. If, however, the pinks of the F_2 generation are self-fertilised or crossed with one another, exactly the

same results are obtained as in the case of the pinks of the F_1 generation, viz. plants will come up a quarter of them with red flowers, a quarter of them with white flowers and the other two quarters with pink ones.

Now how are we to account for these facts, and more particularly for the very peculiar numerical relations existing in the F_2 generation between the three different varieties? The Mendelian explanation is extremely simple. It is that in every specimen of *Mirabilis jalapa* two factors are always present. They may be either both red or both white, or one red and the other white, when the flowers produced by them will be either red, white or pink accordingly. But further—and this is the main point—it is supposed that when the reproductive cells are being formed, namely, the *Oospheres* and the *Pollen-grains*,¹ these factors segregate—that is, separate from one another, and in such a manner as that each reproductive cell contains only one of them. Hence in the case of the plants with the pink flowers half the oospheres which they produce will contain the red factor only, whilst the other half will contain the white factor only, exactly the same thing being true of the pollen-grains. If now for the moment we fix attention on the oospheres containing the red factor, the chances are that when fertilisation occurs, half of them will be fertilised by pollen-grains containing the red factor, and half of them by those containing the white factor; consequently when the seeds thus formed are sown, half of them, viz. those containing two red factors, will produce plants bearing red flowers, whilst the other half of them, viz. those containing a red and a white factor, will produce plants bearing pink flowers. Similarly, if we fix attention on the oospheres containing the white factor, it is easy to see that the final result of fertilisation and subsequent sowing will be a number of plants, half of them bearing pink flowers and half of them bearing white ones. If we put together, then, these results, we see that in the plants belonging to the F_2

¹ The oosphere is the female reproductive cell in all the higher plants, and corresponds to the ovum in animals. Each ovule or immature seed contains one of them. Similarly the generative cells contained in the pollen-grains correspond to the spermatozoa in animals.

generation the proportion between the reds, the pinks and the whites ought to be, if the theory is correct, as the numbers 1 : 2 : 1, which numbers are precisely in accordance with the facts as above described. This will be rendered plainer perhaps by the accompanying diagram, in which the small squares and circles are intended to represent the pollen-grains and oospheres respectively, and the letters R and W the red and white factors.

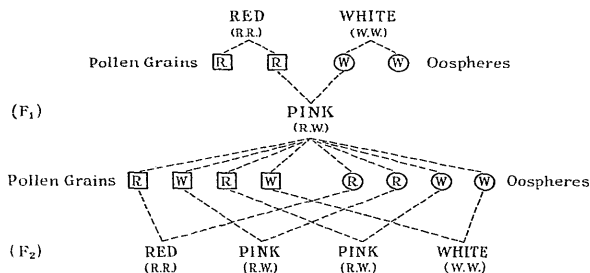


FIG. 33.

Further, it will be seen how, in complete accordance with this theory, the reds of the F₂ generation can only give rise to other reds, the whites can only give rise to other whites, while the pinks must necessarily give rise to all three varieties, and in exactly the same proportions as did the pinks of the F₁ generation.

The theory can be tested in another way. We may put to ourselves the question, What will happen as the result of a cross between the reds and the pinks? Seeing that each red is supposed to contain two red factors and each pink a red and a white factor, it is plain that, if in the formation of their pollen-grains and oospheres the factors segregate as before, we ought, as the result of their coming together again in fertilisation, to get seeds which will grow up into plants, half of them bearing red flowers and half of them bearing pink ones. And this is precisely what happens when the experiment is tried. Similarly, when whites and pinks are crossed, we

get whites and pinks in equal numbers. The results may be expressed thus :

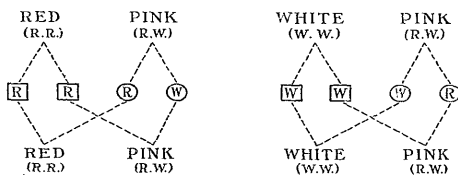


FIG. 34.

Let us consider now a rather different case, viz. that of the Andalusian fowls, which are the result of crossing black fowls with splashed whites, but the colour of which, instead of being intermediate between black and white, is blue, and not, therefore, what we should have anticipated. When, however, two of these blue Andalusians are bred together, we get among their offspring a quarter of them black, a quarter of them splashed white and the two other quarters blue. Evidently here, in spite of the difference, we are dealing with the same kind of phenomenon as before, and one which can be explained in exactly the same way as the red, white and pink varieties of *Mirabilis jalapa*. We have simply to suppose that two factors are again concerned, one for black and another for splashed white, and that when these two happen to come together in the same individual the result is a blue bird. We see also why it is that these blue Andalusians can never be got to yield a pure strain, but always give rise in their offspring to a certain number of blacks and splashed whites in addition to the blues, and always in the same proportions to one another as before.

We come next to a number of important cases in which, although the principle involved is really the same, it is somewhat obscured by what is known as *Dominance*. We will take one of Mendel's own experiments. He crossed a tall variety of the common pea, *Pisum sativum*, with a certain dwarf variety, sowed the seeds and awaited the result. All the plants came up tall. It looked, therefore, as though

the dwarf factor had been entirely suppressed. When, however, these plants of the F_1 generation were self-fertilised and their seeds sown, the F_2 generation sprang up three-quarters tall and one-quarter dwarf. This Mendel explained on the assumption that when the tall and the dwarf factors come together in the same individual, the tall factor, being the more potent of the two, prevents the dwarf factor from producing any visible effect on the plant itself, but that this does not prevent the dwarf factor from afterwards segregating out into half the pollen-grains and into half the oospheres when the time for their formation comes. The accompanying diagram will render this clear, in which T stands for the tall factor and d for the dwarf.

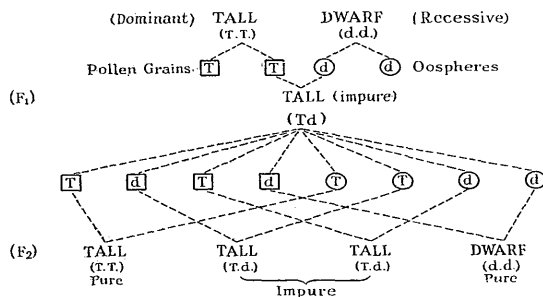


FIG. 35.

That this is the true explanation is proved by the fact that whenever the experiment is tried, the dwarfs (d.d.) of the F_2 generation always give rise after self-fertilisation to dwarfs only, a third of the tall (T.T.) give rise to tall only, whereas the other two-thirds (T.d. and T.d.) give rise to plants three-quarters of them tall and one-quarter dwarf, just like the tall (T.d.) of the F_1 generation. Moreover, the theory can be checked by crossing the impure tall (T.d.) with the dwarfs (d.d.), when half the offspring will come up tall and half dwarf, which is exactly what they should do.

I have to add that in the example just given the tall factor

is said to be the *Dominant* and the dwarf factor the *Recessive* one, and that the two are described as forming a pair of *Allelomorphs*. In *Mirabilis jalapa* the allelomorphs are the red and the white factors, and in the Andalusian fowls they are the black and the splashed white factors, but in neither of these two cases are any of the factors dominant.

Factors for tall and dwarf were not the only pair of allelomorphs discovered by Mendel in the common pea. Certain of these plants produce round seeds and others wrinkled ones, and he showed that this difference was again due to a pair of allelomorphs, in which the factor for roundness was dominant to the factor for wrinkledness. Also, plain pods were shown to be dominant to constricted pods, and flowers borne in the axils¹ of leaves to be dominant to terminal ones and so forth. Moreover, since Mendel's day innumerable experiments similar to his have been carried out in connection with a very large number of both animals and plants, with the result that his Law of Germinal Segregation has been found to be of well-nigh universal application. There is scarcely a character displayed by any organism at any stage of its existence, from the fertilised germ-cell onwards, which does not obey this Law, and which may not be traced back in all probability to the influence of some factor or group of factors behaving in the manner described. Thus T. H. Morgan says in his *Mechanism of Mendelian Inheritance*, p. 27: "Mendelian inheritance applies to all sorts of characters, structural, physiological, pathological and psychological; to characters peculiar to the egg, to the young and even to old age; to length of life; to fundamental taxonomic characters, as well as to superficial characters, and to characters intimately concerned in maintaining the life of the individual, as well as to characters which apparently do not influence survival."

But if this be so, and if by means of these factors the various hereditary characters are passed on from one generation to the next, we can scarcely avoid the conclusion, after what has been stated in the preceding chapters, that the factors in question must somehow be lodged in the chromo-

¹ The angles between leaf-stalks and the stems from which they spring.

somes, or at least be very intimately bound up with them. For has not the reader already been struck with the remarkable resemblance between the way in which the Mendelian factors segregate, and the way in which during maturation the chromosomes do the same, the members of each pair parting company with each other and going into separate cells? To fix our ideas on this subject, let us suppose that in every cell of *Mirabilis jalapa* there is a pair of chromosomes which we will denote by the letters K, K, and that each of these contains—in the case of the red variety—a minute particle, r, representing the Mendelian factor for red. Let us also suppose that in every cell of the white variety there is a corresponding pair of chromosomes, K, K, and that each of these contains a minute particle, w, representing the Mendelian factor for white. Then if we distinguish between these two slightly different sorts of chromosomes by employing the symbols K_r and K_w , it is clear that there will be one K_r in every pollen-grain and in every oosphere formed by the red variety, and similarly one K_w in every pollen-grain and in every oosphere formed by the white variety. When, however, one of these varieties is fertilised by the other, the K_r and the K_w chromosomes will be brought together, so that in every cell of the pink hybrids produced by them both a K_r and a K_w will be present. Consequently, when afterwards at the halving division these hybrids themselves form pollen-grains and oospheres, the chromosomes—and along with them the Mendelian factors—will again segregate, and the result will be that half the pollen-grains will contain a K_r and half will contain a K_w . As the same thing will happen, of course, in the case of the oospheres, it is easy to see how, as the result of their chance unions with one another, plants will be produced in the F_2 generation, a quarter of them red, a quarter of them white and two-quarters pink.

What is so extremely interesting here is the manner in which the known behaviour of the chromosomes, as viewed under the microscope, tallies with, and apparently helps to explain, the behaviour of the Mendelian factors as determined by experiments in interbreeding. Moreover, as we

shall see presently, the theory of their very close relation to one another has received ample confirmation in other ways.

II. *The Law of Independent Assortment.*—This asserts that when in any species of plant or animal two or more pairs of allelomorphs have been shown to be present—although of course there may be present any number of other ones besides, not yet detected—the members of these pairs will segregate independently of each other. Suppose, for example, we take a tall pea with round seeds, and having therefore the factorial constitution T.T.R.R., and apply its pollen to the stigma of a dwarf pea with wrinkled seeds, and having therefore the factorial constitution d.d.w.w., we shall get plants in the F₁ generation in which all the four factors, T. d. R. and w., will be present, thus :

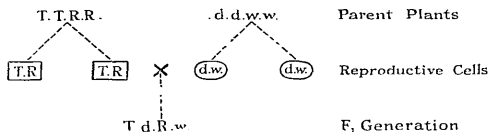


FIG. 36.

Also, seeing that the factor T is dominant to d, and R is dominant to w, these plants of the F₁ generation will not exhibit either of the recessive characters—dwarf or wrinkled—but will appear simply as tall with round seeds. When, however, in due course they form their pollen-grains and oospheres, segregation will take place in both of the following ways :—

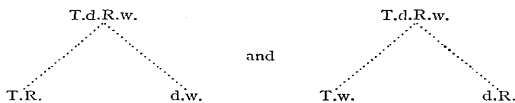


FIG. 37.

Hence among both the pollen-grains and the oospheres there will be four different kinds, and these, according to the Law of Independent Assortment, will be produced in equal numbers. Consequently, when fertilisation takes place no less than 16 combinations will be possible, and

on an average these will again occur in equal numbers. The subjoined table is intended to make clear how exactly this is brought about.

		Pollen Grains				
		T.R.	T.w.	d.R.	d.w.	
Oospheres	T.R.	T.T.R.R.	T.T.R.w.	T.d.R.R.	T.d.R.w.	Possible Com- binations
	T.w.	T.T.R.w.	T.T.w.w.	T.d.R.w.	T.d.w.w.	
	d.R.	T.d.R.R.	T.d.R.w.	d.d.R.R.	d.d.R.w.	
	d.w.	T.d.R.w.	T.d.w.w.	d.d.R.w.	d.d.w.w.	

FIG. 38.

It will be found, however, on examining this table that several of the combinations repeat themselves, so that they may be reduced in number to 9. Again, owing to the dominance of the tall and the round factors over the dwarf and the wrinkled ones, it will *appear*, when the plants grow up, that these 9 have been further reduced to 4, viz. to tall with round seeds, tall with wrinkled seeds, dwarfs with round seeds and dwarfs with wrinkled seeds. And these four sets will occur in numbers represented by the proportion 9 : 3 : 3 : 1 thus :

The Nine entirely distinct Combinations.	Number of Times each Combination occurs.	Patent Results in Plants produced.
T.T.R.R. *	1	T.R. Tall with Round seeds
T.T.R.w.	2	
T.d.R.R.	2	
T.d.R.w.	4	
T.T.w.w. *	1	T.w. Tall with Wrinkled seeds
T.d.w.w.	2	
d.d.R.R. *	1	d.R. Dwarf with Round seeds
d.d.R.w.	2	
d.d.w.w. *	1	d.w. Dwarf with Wrinkled seeds
16		

FIG. 39.

It will be observed that the ratio of the tall plants to the dwarfs is 12 to 4, that is, 3 to 1, and that the ratio of the plants with round seeds to those with wrinkled seeds is also 3 to 1. But this is the ratio which was previously observed when only one pair of Mendelian factors was being considered. Hence we see once more that each pair of factors segregates independently of the rest; in other words, that the Law of Independent Assortment holds good.

That in cases like the above there are real differences of inner constitution among plants which are apparently alike can be proved by crossing them with the double recessive—that is in this particular case with a pea-plant having the constitution d.d.w.w. Thus the reader will find, if he will take the trouble to work the thing out, that different results will be obtained by crossing the first four combinations in the above list with a d.d.w.w. plant, although the former are all outwardly indistinguishable as tall plants with round seeds. It is, in fact, by experiments of this kind that the Law of Independent Assortment has been established.

Note that the asterisk affixed in the above table to the combinations T.T.R.R., T.T.w.w., d.d.R.R. and d.d.w.w. is to indicate that each represents a pure strain, *i.e.* that, when self-fertilised, it will only give rise to its own kind. For example, dwarf plants with round seeds (d.d.R.R.), if uncontaminated with other pollen, will always produce offspring similarly constituted, inasmuch as both the tall and the wrinkled factors have been eliminated.

If, now, we inquire as to the relation in which the Law of Independent Assortment stands to the behaviour of the chromosomes, we need only refer to what has been previously said about the different ways in which the chromosomes assort themselves, when the members of the several pairs part company with one another, as they do during maturation. Once more, to fix our ideas, let us take, for example, a pea-plant of the F_1 generation having the constitution T.d.R.w. Then, if we suppose that the allelomorphs T and d are represented by particles situated in one pair of chromosomes, and that the allelomorphs R and w are represented by particles situated in another pair, it

will follow when maturation occurs that not only the chromosomes, but the particles situated in them, will separate from one another after the manner already described. Also, the Law of Independent Assortment will hold good, because the separations will take place in the two different ways shown in the accompanying diagram.

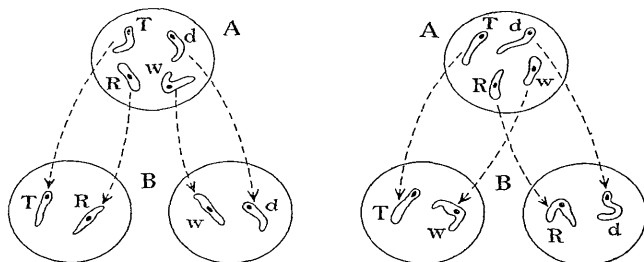


FIG. 40.—A, A. The nuclei (diagrammatic) in two of the ordinary cells of a T.d.R.w. plant, several other pairs of chromosomes, besides those shown, being present.
B, B. The two different ways in which the chromosomes will assort themselves, when maturation takes place.

Moreover, among both the pollen-grains and the oospheres we shall find all the four combinations, T.R., d.w., T.w. and d.R., represented in about equal numbers; and these as the result of fertilisation will give rise to plants constituted in all the different ways set forth in figs. 38 and 39.

But to pass on. Since Mendel's day it has been proved by numerous experiments that there are certain exceptions to this Law of Independent Assortment—exceptions about which there has gathered a considerable amount of interest. Moreover, as a little reflection will show, there must necessarily be such exceptions, if it be really true that the Mendelian factors are represented by particles situated in the chromosomes. Suppose, for example, that in a given organism the number of pairs of *chromosomes* in each cell is 12. Then seeing that the number of pairs of *factors* must be very much greater than this, mounting up frequently to

several hundreds and even thousands, it is obvious that in each chromosome there will be not one representative particle only, but a very considerable collection of them. Hence in the example I have supposed, although in the formation of the reproductive cells any two arbitrarily selected pairs of factors will as a rule segregate independently of one another, yet every now and again—about once in every twelve cases—they will not do so, because the particles representing the pairs of factors in question happen to be situated in the same pair of chromosomes. Thus if A_1 and A_2 represent one of these pairs of particles, and B_1 and B_2 the other pair, we shall get

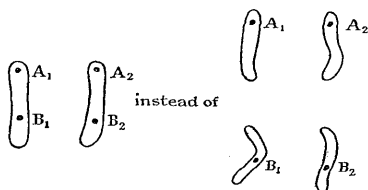


FIG. 41.

Consequently, when in maturation the number of the chromosomes in each cell is halved, the particles A_1 and B_1 , being in the same chromosome, will necessarily cleave together, as will also the particles A_2 and B_2 . Hence the characters in the plant which will ultimately result from the presence of these particles will also cleave together, and we shall get an instance in which the Law of Independent Assortment is not strictly obeyed. Now, whenever this sort of thing occurs, it is said to be a case of *Linkage*, and it clearly tends to confirm the theory that the Mendelian factors are somehow represented by particles situated in the chromosomes.

The conclusive proof that this is really so is supplied by the extraordinary series of experiments carried out by T. H. Morgan on the fruit-fly, *Drosophila ampelophila*. It is an insect which especially lends itself to this purpose, because not only is it extremely prolific, but it exists in a

great number of varieties—a circumstance which permits, therefore, of an almost endless number of experiments in intercrossing. Another important point about it is, that in each of its cells there are only four pairs of chromosomes, whereby the chances are enormously increased of detecting cases of linkage. Again, these four pairs of chromosomes can be clearly distinguished from one another by their different shapes and sizes, as seen under the microscope. T. H. Morgan at the time of the publication of his *Mechanism of Mendelian Inheritance* had already detected in this insect nearly a hundred pairs of factors, and had made the remarkable discovery that they fell into four distinct linkage groups, corresponding, that is, to the number of the pairs of chromosomes.¹

Connected with the first pair of chromosomes there are, it would appear, forty-seven different pairs of factors all linked together; connected with the second pair of chromosomes there are twenty-seven pairs of factors similarly linked together; while the other two linkage groups contain twenty-two and two pairs of factors respectively. Moreover, the smallness of the fourth group, with its two pairs of factors only, is in striking correspondence with the comparative smallness of the fourth pair of chromosomes as directly observed. It would be difficult perhaps to find a more conclusive proof, than that furnished by these experiments, of the theory which we are considering, viz. that the Mendelian factors are really represented by certain minute particles located in the chromosomes. And if this be true in the case of the fruit-fly, what is there to hinder the assumption that the same is true in the case of all other organisms, and especially when fresh examples of linkage are continually being discovered in all sorts of different plants and animals? Thus linkages have been shown to exist in both the edible and the sweet-pea, in tomatoes, stocks, groundsel, wheat, oats, Indian corn, the primrose and the snapdragon, as also in rats, fowls, locusts and silkworms.² Again, as bearing the

¹ T. H. Morgan, *The Physical Basis of Heredity*, p. 86.

² *Ibid.*, p. 86.

theory out, no single instance has yet been found in which the number of the linkage groups exceeds the number of the pairs of chromosomes.¹

But the discoveries which have been made in recent years do not end at this point. T. H. Morgan has brought forward evidence to show that the representative particles or *Genes*, as he calls them, are arranged in each chromosome in a certain linear series, and, what is still more remarkable, that one can tell with a greater or less degree of precision whereabouts in this linear series any particular gene is located.

Now it would be impossible, without going into an immense amount of detail, to present the evidence for this in full. The following considerations, however, may help to at least a partial understanding of it.

In the first place, the linkage between the genes belonging to any one of the four pairs of chromosomes is not absolute ; it is sometimes broken, and in such a manner as to suggest the idea that, when during maturation the chromosomes conjugate with one another, a certain number of the genes in the paternal chromosomes cross over in blocks and exchange places with the corresponding blocks in the maternal chromosomes. Thus if we represent the genes in one of the paternal chromosomes by the series 1, 2, 3, 4, 5 to n , and the genes corresponding to them in the maternal chromosome by the series 1', 2', 3', 4', 5' to n' , it will sometimes happen that after conjugation the arrangements will be 1', 2', 3', 4, 5 to n , and 1, 2, 3, 4', 5' to n' , the block 1, 2, 3 having exchanged places with the block 1', 2', 3'. Or it may happen that the block 1, 2, 3, 4 will exchange places with the block 1', 2', 3', 4', or there may be some other similar exchange. Now, according to T. H. Morgan, it is just when the chromosomes are observed twisting round one another at the time of conjugation, in the manner described in Chapter XVII, that the exchanges in question take place. The chromosomes, he thinks, become ruptured—or something equivalent to that occurs—and the separated portions then join up somewhat after the fashion shown in

¹ T. H. Morgan, *The Physical Basis of Heredity*, p. 133.

the accompanying diagram, which is intended to represent the successive stages.

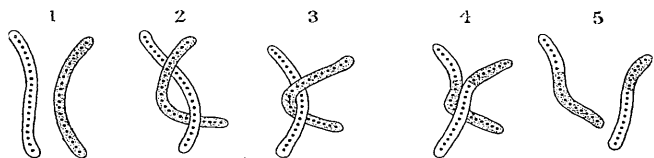


FIG. 42.

But how is it known that the genes as depicted in this diagram form a definite linear series? Granting that they actually do form such a series, it will at once be evident that the chances of any two genes becoming separated during conjugation will depend upon their distance apart within the chromosome. Suppose that there are 50 genes. Then seeing that there are 49 places at which a rupture may occur, genes numbers 4 and 40, for example, which are 36 places apart, will be twelve times more likely to get separated from one another than, say, numbers 25 and 28, which are only 3 places apart. Hence the frequency with which any two genes, belonging to the same chromosome, become separated from one another as the result of conjugation affords a clue as to their distance apart within the chromosome. This at all events, without entering into further details, will help perhaps to explain the general principle on which T. H. Morgan has been able to construct his very remarkable chart, showing the relative positions of the genes in the chromosomes of the fruit-fly.¹ The illustration given below is based upon this chart. It is intended to

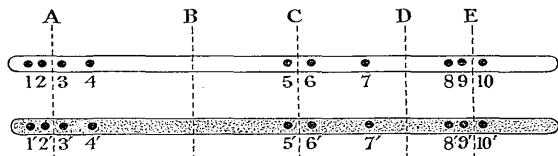


FIG. 43.

¹ T. H. Morgan, *Mechanism of Mendelian Inheritance*, p. 67; also the frontispiece.

represent the first pair of chromosomes, while the dots inside them represent ten specially selected pairs of genes.

Now the characters determined by these ten pairs are as follows :—

- | | | | | | | | | |
|----|-----|-----|--------|-------------------------------------|---|-------------|----|---------|
| 1 | and | 1' | affect | colour of the insect's body ; | 1 | grey, and | 1' | yellow. |
| 2 | „ | 2' | „ | colour of the eyes ; | 2 | red, and | 2' | white. |
| 3 | „ | 3' | „ | markings on the abdomen. | | | | |
| 4 | „ | 4' | „ | shape of the wings ; | 4 | normal, and | 4' | bifid. |
| 5 | „ | 5' | „ | colour of the eyes. | | | | |
| 6 | „ | 6' | „ | size of the wings ; | 6 | large, and | 6' | small. |
| 7 | „ | 7' | „ | colour of the body ; | 7 | grey, and | 7' | black. |
| 8 | „ | 8' | „ | degree of development of the wings. | | | | |
| 9 | „ | 9' | „ | shape of the wings. | | | | |
| 10 | „ | 10' | „ | shape of the compound eyes. | | | | |

In passing, I would ask the reader particularly to notice, in the above list, the extraordinary arrangement, or rather the total lack of arrangement, which exists among the several pairs. The genes affecting the body, the wings and the eyes, and determining their different colours, shapes and sizes, seem to be inextricably mixed up, their spatial relations to one another not in the least answering to the spatial relations of those parts of the body over which, as development proceeds, they will exercise their controlling influence. This is a point, as it appears to me, of the utmost importance, and one to which I shall have to return in the next chapter.

From the numerous experiments actually performed, the conclusion was drawn that in certain cases the genes 1 and 2 had exchanged places with 1' and 2', while the others, 3 to 10 and 3' to 10', had remained as they were, or in other words, that the rupture of the chromosomes previous to their joining up again had occurred at points indicated in the above diagram by the line *A*. In other cases, however, the rupture had apparently occurred somewhere between the genes 4, 4' and 5, 5'—we will say at *B*—while in others the evidence pointed to ruptures at *C*, *D* and *E*. Again, in several instances there were no ruptures at all,

and consequently no crossings over, while in one particular instance there had apparently been two ruptures, one at *B* and another at *E*, due doubtless to twists at two places in the chromosomes at the time of their conjugation.

Now the extraordinary nature of these and of a large number of other similar experiments conducted by T. H. Morgan and his coadjutors at the University of Columbia, U.S.A., does unquestionably seem to provide a very firm basis for the theory which they have propounded. To state it once more, the theory is not only that the chromosomes are intimately concerned in the handing on of the various hereditary characters, but that these characters are somehow bound up with certain material particles, the so-called genes, which in each chromosome form a definite linear series, and whose positions within the series can under certain favourable conditions be ascertained.

It is specially to be noted that the Mendelian Laws, together with the more recent discoveries intimately connected with them, confirm very strongly the conclusion that in the nucleus of the germ-cell—as well as in the nuclei of all the other cells of the body except the reproductive ones—there are only two sets of genes or determinants, viz. those derived from the father and from the mother respectively.

Granting, however, that as the result of further investigations the theory, as explained in the latter part of this chapter, will finally take its rank among the undisputed generalisations of science, having been shown to apply not only to the fruit-fly but to organisms of every description, the question still remains: To what extent will it have really brought us on our way towards the solution of the great problem which has occupied so much of our attention in these last three chapters?

CHAPTER XX

FAILURE OF THE SEARCH

THE Factorial Hypothesis as described in the last chapter affords a striking illustration of the way in which two entirely distinct lines of investigation may converge and lead up to the same general conclusion. On the one hand we have the numerous experiments in interbreeding which have been undertaken in recent years in continuation of the work of Mendel, and on the other hand we have those important discoveries which relate to the peculiar behaviour of the chromosomes, as seen under the microscope, whenever the cells of any plant or animal are undergoing division. And these two very different classes of facts not only fit into one another in the most extraordinary fashion, but would seem at first sight to furnish us with the kind of explanation of which we have all along been in search.

Further reflection on the subject, however, will tend, I think, very considerably to modify this opinion, and will lead rather to the conclusion that, true though the factorial hypothesis may be so far as it goes, it still leaves us very much in the dark as to the real cause of individual development. Indeed in some respects it serves only to deepen the mystery.

I. And first—to revert to Weismann's theory—we saw in Chapter XVIII that he conceived of the chromosomes as composed of a number of entities to which he gave the name of *ids*, and supposed that each of these *ids* was provided with a complete set of determinants—with all, in fact, which were necessary for the production of a fully developed individual. But these determinants—to which the genes of the Factorial Hypothesis very closely correspond

—were not thought of by him as a merely loose array, but as built up in the case of each id into an architectural whole, a very definitely organised structure, answering to the very definitely organised structure of the plant or animal which was to be. And his reason for thinking so was that it seemed to him that, for orderly development to take place, there must necessarily be some relation of this kind subsisting between the original cause hidden in the germ-cell and its ultimate effect, viz. the adult individual.

When, however, we pass on from Weismann's to the Factorial Hypothesis we find nothing in the latter which answers to an id. Far from being built up into any architectural whole, the genes are distributed among a number—and sometimes a very large number—of chromosomes, which latter, although they unite to form a network during the intervals between successive cell-divisions, are nevertheless shown to be distinct bodies, inasmuch as they separate again from one another whenever a cell-division occurs.

Again, according to the Factorial Hypothesis, the genes are arranged in each chromosome in a *linear* series—that is, they stand in certain spatial relations to one another which cannot possibly correspond to the three-dimensional spatial relations of the organs whose development they are supposed to control. Far more important, however, is the consideration that the genes which have to do with the production of any particular class of organs, as for instance the eyes, the wings and the body colour of the fruit-fly,¹ are scattered about in the chromosomes at various distances apart and in an apparently quite irregular manner. Also, the members of each set are to be found, not in one pair of chromosomes only, but sometimes in all the four pairs. The following diagram, based upon data supplied by T. H. Morgan,² is intended to illustrate this, the four pairs of lines representing the four pairs of chromosomes, and the letters E, W and B marking the positions of the genes

¹ The little creature on which T. H. Morgan bestowed the greater number of his observations.

² In his *Critique of the Theory of Evolution*.

influencing respectively the eyes, the wings and the body colour of the insect.

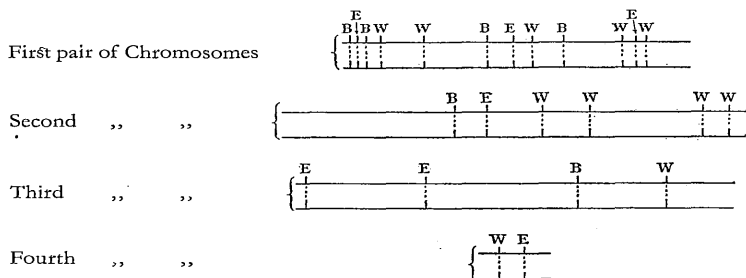


FIG. 44.

The above will show at a glance how completely the idea of anything in the least corresponding to Weismann's architectural structures, his idea, has been dissipated by the Factorial Hypothesis as worked out by Morgan, and how very much more difficult it has become in consequence to regard the mere materials of which the chromosomes are composed as being *in themselves sufficient* to bring about embryonic development. How, for example, do the several influences emanating from the various points marked E in the diagram conspire together to affect the colour of the eyes, while from other points not marked in the diagram, but scattered about in like irregular fashion, influences must presumably be proceeding which will determine their size, their shape, and all their elaborate internal arrangements?

Moreover, if not only in the fruit-fly, but in all the higher forms of animal life, the genes controlling the development of each organ are scattered about among the chromosomes in the same apparently haphazard manner, how, once more, do particles thus separated from one another manage to bring about the final result? How, too, by means of any arrangement of this kind—or rather utter lack of arrangement—is there secured that perfectly harmonious succession of stages through which the embryo has to pass on its way to maturity, as briefly described

in Chapters XIV to XVI? It is not only the differentiation of the various sorts of cells and tissues which has to be accounted for, and the way in which they are built up into complex organs, all having their definite shapes, sizes and relative positions, but an explanation is required of all those remarkable movements of cells and of entire masses of cells which accompany development, as for instance, the infoldings and outfoldings of the three primary layers concerned in the formation of the digestive, the respiratory and the nervous systems, and of those two very special organs of sense, the eyes and the ears (Chapter XVI). How do irregularly distributed material particles, endowed simply with the ordinary physical and chemical properties, contrive to produce these effects? Then there is, besides, the opening and the closing of sundry apertures, the hollowing out and the solidification of sundry tubes, and, more marvellous perhaps than anything else, the way in which the nerves budding out from both sides of the spinal cord pursue their tortuous paths through a perfect maze of other tissues, till each at last reaches its proper destination in the gland, the muscle or the group of muscles which it is to actuate, or in the sense organ from which it is to carry back impressions to the brain. Consider, too, in the case of birds and mammals those curious, purely temporary structures, the yolk-sac, the allantois, the amnion and the placenta, and the changes which take place in the circulation of the blood at the time of hatching or of birth, accompanied, as they are, by the closure of the foramen ovale and the conversion of the ductus arteriosus into a solid cord (Chapter XV). Are all these extraordinary happenings likewise simply the consequence of certain material forces located in the genes? Again, how are we going to explain along lines such as these the metamorphoses of insects? A butterfly, as is well known, passes through the three stages of caterpillar, chrysalis and perfect insect or imago. But the process involves, after a certain period has elapsed, an almost complete reconstruction of both its external and its internal parts. Thus four wings are developed, and a pair of compound eyes with

their innumerable facets, neither of which were possessed by the butterfly in its caterpillar state, while its mouth, which was originally adapted for biting, becomes transformed into a very efficient sucking instrument, and is provided for that purpose with a remarkably constructed hollow tongue. The point of course is: If there are genes or determinants which have to do, as this theory assumes, with the production of these organs, how is it that so many weeks and occasionally months have to go by—during the whole, that is, of the caterpillar stage of existence—before they show any signs of activity? What is it in the genes which not only causes the organs in question to appear, but determines the proper times for their appearance?

Besides these difficulties there are others which suggest themselves in connection with the hereditary transmission of instincts and of purely mental characteristics. Why, for instance, does the garden spider spin a web of exactly the same complicated pattern as that of its parents (Chapter XXIII), and why, in the case of man, are mathematical and musical abilities so often handed on from father to son? Are these things also to be attributed solely to the physical and chemical properties of certain material particles?

But perhaps it will be said: "Surely the facts brought to light by Mendelism, and those other facts, so remarkably agreeing with them, disclosed by the microscopic study of cells, do very strongly point to the conclusion that the chromosomes, or rather the material particles contained in them, are very intimately concerned in the passing on from one generation to the next of at least all the physical characteristics." Well that, as I have tried to show in the preceding chapters, must admittedly be the case; but it is an altogether different matter to claim for the said particles that they furnish a *complete explanation* of all that occurs in the development of the individual, and that they *alone*, therefore, constitute its sufficient cause. In a newspaper establishment the letters of the alphabet arranged in their several pigeon-holes may be essential for the production of the printed page, but the printed page would never see the light apart from the work of the compositor. So, too,

the colours irregularly spread out on an artist's palette may be essential for the production of his picture, but clearly there would be no picture if there were no artist. Or, if the blues had been wanting on his palette, he could never have given us a typical Italian sky, nor could he have painted any of the gorgeous effects of sunset had not his pigments included the warmer tints—the yellows, the reds and the crimsons.

I would suggest, then, at this point that although the genes or determinants—whatever we may please to call them—are insufficient in themselves to account for all those wonderful processes which take place in embryonic development, they nevertheless in some sort condition it, and that its real underlying cause, whatever it may ultimately turn out to be, is to a considerable extent limited by them. But the limitation may be compared with that of the artist who, having only sepia to work with, is obliged to produce his pictures in monochrome.

Although the subject just touched upon is one about which I shall have more to say later on, I should like to call attention here to certain very interesting experiments which were performed by Herbst on the developing eggs of the sea-urchin, and which, if analogy may count for anything, would appear to favour the view above expressed.¹

Sea-water holds in solution not only common salt, which is a compound of chlorine and sodium (NaCl), but small quantities of other substances containing the elements oxygen, hydrogen, carbon, sulphur, phosphorus, calcium, magnesium and potassium, of which the symbols are respectively O, H, C, S, P, Ca, Mg and K. Now it was found that if any of these elements were withdrawn from the sea-water in which the eggs were placed, the proper development of the eggs was in some way or another interfered with. Thus without the common salt—the chlorine and the sodium (Cl and Na)—the original cell would not segment—divide, that is, so as to form the morula or mulberry mass; without the calcium it might divide, but the daughter-cells so produced would not cohere;

¹ Jenkinson, *Experimental Embryology*, pp. 141-152.

without the sulphur and the magnesium the archenteron would not form; and again, in the absence of carbon dioxide (CO₂), sulphur, calcium and magnesium, there would be no skeleton, and so forth. The results of these experiments may be tabulated thus, the crosses in the several rows indicating the elements which were found to be essential, if the effects set forth in the first column were to be produced.

	H ₂ O	CO ₂	Cl	S	Ca	Mg	Na	K	Alkaline solution
Fertilisation						×		×	×
Segmentation			×				×		
Cohesion of Cells					×				
Movement of Cilia						×		×	×
Osmosis	×				×			×	
Formation of Archenteron				×		×			
„ „ Skeleton		×		×	×	×			
„ „ Pigment				×					×
„ „ Muscles					×			×	

FIG. 45.

Now just as it would be absurd to maintain that the mere chemical substances, sulphur and magnesium, were sufficient *in themselves*, without any directing influence, to give rise to the archenteron, so I conceive it to be with the substances of which the determinants or genes are composed—in the part, that is, which they have to play in the development of the individual. And there would seem to be all the more reason for taking this view of the matter, when we find T. H. Morgan himself saying: “The basis of the chromosome is a chain of *chemically complex substances*,” and again: “On the factorial hypothesis the factors are conceived as *chemical materials* in the egg which, like all chemical bodies, have a definite composition.”¹

II. But there is another aspect of this subject to be considered. Besides postulating the existence of his ids, Weis-

¹ T. H. Morgan, *Mechanism of Mendelian Inheritance*, pp. 169, 226. The above italics are my own.

mann imagined them to be continually undergoing disintegration as development went on, except of course in the case of those specially favoured cells forming the germ-track.¹ It was in this way that he sought to account for the gradual differentiation of the various classes of cells and tissues. Each of the cells among those first produced was supposed to contain in its ides all the determinants which were necessary for the construction of a complete individual. As time went on, however, and disintegration set in, only a certain number of these determinants would be found in any particular cell, until by and by in each cell only one perhaps or a very few of them would be present. After this, it was supposed that the determinants began to break up into still smaller fragments, the so-called biophors, and that these, making their way through the delicate membrane surrounding the nucleus, got out into the general protoplasm of the cell and there effected its transformation into a cartilage cell, a muscle cell or a nerve cell, as the case might be.

But this entire conception, most ingenious as it certainly was, is no longer accepted to-day. The whole of the available evidence goes to show that the nuclei in all the cells of the body are constituted alike, and that there is no such disintegrating process as Weismann supposed. Some of this evidence has already been given at the end of Chapter XVIII, but there is just one other experiment of a confirmatory kind to which I should like to refer, because it is particularly interesting.² The embryo of a certain species of frog was taken at the stage when the optic cup had already formed, but when the piece of external ectoderm opposite it had not yet begun to fold in to form the lens.³ This piece of external ectoderm or outer skin was then removed, and another piece from another part of the body was put in its place, with the truly amazing result that it shortly afterwards began, as the other would have done, to fold in and to transform itself, first into a detached hollow vesicle

¹ See for full account Chapter XVIII, pp. 244-246.

² Jenkinson, *Experimental Embryology*, p. 275.

³ See end of Chapter XVI, pp. 219, 220.

and then into a properly shaped transparent lens. Hence it would appear that in a frog at least, any piece of the external skin, no matter where it may be situated on the general surface of the body, must contain the requisite determinants or genes for producing that highly specialised organ, the lens of an eye.

Consider now what this implies. It implies, along with the other experiments previously described,¹ that although every cell in the body is equipped with a complete set of determinants, it is only a certain few of them which in any particular cell or group of cells produce an effect. All the others remain, so to speak, dormant, a state from which they can only be aroused under special circumstances, as when, for instance, some lost part, like a lobster's claw, has to be regenerated, or a *Lumbriculus* is cut in two,² or when, as in the last described experiment, they are transferred in a piece of skin containing them from one region of the body to another.

But this immediately raises the question in a very acute form as to what, after all, is the real cause of differentiation. Why, if the cells in their inner constitution are fundamentally all alike, should they diverge from one another in so remarkable a manner and gradually take on such totally different characters? Why should some become bone and others muscle and others nerve, and why should they do this, not in haphazard fashion, but so as to build up that definitely arranged and most marvellous structure, the adult form with all its intricately interrelated tissues, organs and systems? With Weismann's disintegrating idea clean swept away, we seem further off than ever from any merely mechanical solution of the mystery.

It may be said, and indeed it has been said, that what any particular cell or group of cells may ultimately become depends upon its precise position in relation to the other cells of the body, as in the case of the piece of transferred ectoderm in the experiment with the frog, or in the case of the dislocated cells in those experiments in which certain developing embryos were subjected to pressure between

¹ See Chapter XVIII, pp. 253-256.

² See Chapter XVIII, p. 254.

slips of glass (see Chapter XVIII). In a sense, of course, the above statement is true; position undoubtedly has something to do with these results, but it can no more be said to be the cause of them, than if it were said of the nave of a cathedral that position had been the cause of the stones arranging themselves into a vault and a clerestory above, and into piers and pier-arches below. Hence to avoid so manifest an absurdity, the theory has been advanced by Driesch and others, that differentiation is the result of a number of peculiar forces exerted by the cells upon one another, but which only successively come into play as the various stages in development are reached. It has been suggested, too, that although the nuclear material is practically identical in all the cells of the body, their cytoplasm—*that is, the protoplasmic substances surrounding their nuclei*—exhibit certain slight differences even from the first.¹

From this lack of homogeneity it follows that when presently segmentation begins and the cytoplasm of the fertilised egg-cell becomes parcelled out among a number of daughter-cells, the latter are no longer precisely similar. The theory, then, is that this initial lack of homogeneity, slight though it may be, causes the cells to act and react on one another, and to produce differences in them which go on increasing in number and extent during the whole period of development. A cell *A*, for example, because of its cytoplasmic difference from cell *B*, becomes sensitive perhaps to a peculiar influence emanating from the latter. This influence, whatever its exact nature may be, stirs up in *A* a greater or less number of its determinants from their dormant condition. These by reacting on the cytoplasm of the cell bring about a certain change in its character, thereby rendering it sensitive to the influence of some other cell, say of *C*, and at the same time causing it perhaps to rouse into activity a number of determinants belonging to cell *D*. Thus, and with the assistance of certain other forces proceeding from the environment, it is supposed that all the highly differentiated structures of the adult

¹ See additional note at end of this chapter.

organism gradually arise, and that, although in every cell of the body there is always a complete set of determinants, only a limited number of them in each particular class of cells are given the opportunity, so to speak, of asserting themselves and of revealing their true nature, unless indeed some lost organ has to be restored.

Against such a theory, however, very serious objections may be urged.

To begin with, there is its extremely hypothetical character. What proof is there that any such influences as those imagined really exist; and how, if they exist, are we to conceive of them as carrying out their prodigious task, for prodigious it must needs be, if we bear in mind all that has been said in previous chapters about the well-nigh infinite complexity of the human body?

It has been suggested that the influences in question might be compared with those undoubted influences which are frequently exerted upon organisms by purely external agencies. Gravity, for example, in a quite peculiar manner affects the growth of plants, causing their main stems to shoot upwards, as is conspicuously seen in the case of larches and Scotch firs planted on the side of some steep declivity. But why "upwards" instead of "downwards," if the effect is always "downwards" when gravity is acting on merely inanimate objects? ¹ The only answer which in our present imperfect state of knowledge can be given, is that larches and Scotch firs are not inanimate objects, but living things, and that this upward perpendicular growth of theirs is due not to the *direct* action of gravity, but to something in them which in a unique way is affected by gravity, and which calls forth what, for lack of a better term, we must describe as a "vital response." Now a "vital response" differs from a purely mechanical effect in two ways. First, it is not in any way obviously related to the stimulus which calls it forth, and secondly, it is always purposive in character, it serves a definite end. The end served in the case just referred to is that the trees

¹ The case of an ascending column of smoke or of an ascending balloon is no real exception.

may be able to spread out their foliage in such a manner as to offer the greatest extent of surface to the light and air, light and air both being necessary to their existence (see Chapter IV). As a contrasted example of a purely mechanical effect, we may point to the shape of our own coast-lines with their various promontories, bays and lesser indentations. These are the result of the ceaseless action of the waves beating upon the rocks of various degrees of hardness which abut upon our shores. Thus the great semicircular bay sweeping round from Portland Bill to Start Point is due to the superior resistance of the rocks forming those two headlands, combined with the comparative softness of the intervening strata—a softness which has enabled the sea to encroach effectually there upon the land.¹ But in this case we can see clearly how the result has been brought about by the operation of certain well-known and thoroughly understood forces. Moreover, we are unable to trace in the result the accomplishment of any assignable purpose. Nothing in the nature of an end has been gained by the formation of the bay. Hence and for these two reasons it differs essentially from a “vital response.”

Further, if, as the theory we are discussing assumes, differentiation is brought about among the cells of a developing organism by certain actions and reactions which are essentially of the same order as these “vital responses,” then naturally we want to know, How did these “vital responses” first arise? By what extraordinary combination of purely physical forces, such as gravity, cohesion, electrical attractions and repulsions, chemical affinity, etc., were they produced, and did they come to possess their peculiar purposive character—purposive, because of the countless purposive structures to which they give rise? Until this question is answered, the explanation offered is really no explanation whatever. To say that the action of the cells upon one another in a developing embryo may be explained by comparing it, for example, to the action of gravity upon plants, causing their stems to shoot upwards, leaves us no wiser than before, seeing that we are

¹ Marr, *The Scientific Study of Scenery*, pp. 336, 337.

still entirely ignorant as to why plants should respond to gravity in the way they do.¹

Or, to come to details, let us consider what must happen in the case of any of the more complicated organs during its embryonic stages. Take for instance the liver. Now the liver consists primarily of an immense number of so-called liver cells which differ *in toto* from all other cells in the body. According to this theory, then, they must have been developed in the position in which we find them, as the result of certain influences proceeding from cells in their more or less immediate neighbourhood, and possessed of the peculiar power of arousing in them those particular determinants which give rise to liver cells—determinants which, as we have seen, must be supposed to be present in all cells alike. But the liver does not consist of liver cells only. It is penetrated in every part by the ramifications of the bile duct, of the hepatic artery, of the hepatic and portal veins and their capillaries, as well as by innumerable nerve filaments. Moreover, it is bound together into a compact whole by connective tissue. Now as all these various elements are composed of cells—cells of very different kinds—we want to know, why, when by their close juxtaposition they were exposed to the same mysterious influences as were the liver cells, did they not become liver cells themselves? How was it that they assumed all this diversity instead?

Questions precisely similar arise in connection with nearly every other organ in the body. We find tissues in the closest proximity to one another, and subjected, therefore—so we must suppose—to the same mysterious influences, nevertheless exhibiting the greatest possible differences. Of this we have an excellent illustration in the case of the retina, where the highly differentiated and quite unique layer of the rods and cones is in immediate contact behind with the layer of dark hexagonally shaped cells, which serve the purpose of absorbing any stray light which may pass in through the pupil. But how was it that these two

¹ Nor are we in the least helped to the understanding of what really happens by labelling it "negative geotropism."

layers, both of them modifications of the original optic cup, came to take on such widely different characters, if these different characters are to be attributed, as the theory would have us believe, to the action of certain obscure and elsewhere utterly unknown forces emanating from cells at no very great distance off and practically all alike ?

But it is needless to pursue the subject any further. What I have tried to show in this and the last three chapters is that, so long as we proceed along purely mechanistic lines, every attempt to arrive at the real, the sufficient cause of embryonic development, is doomed to failure.

Weismann thought that in order to account for the highly organised structure of the adult individual there must be some highly organised minute structure—an id—corresponding to it in the original germ-cell ; he also thought that, by the gradual disintegration of the id, it was possible to account for the differentiation of all the various tissues ; but, as we have seen, both these ideas of his, owing to the logic of facts, have had to be abandoned, with the result that we are left very much in the same state of ignorance as when Darwin long ago put forward his theory of Pangenesis.

True, it has seemed every now and again as though we had got hold of a clue which would enable us to penetrate the mystery, but the further the clue has been followed out, the further has it led us away from the required solution. In saying this, not for one moment do I desire to undervalue the assured results of scientific investigation. The facts of Mendelism and the marvellous discoveries made by the microscope in reference to the minute structure of cells and the behaviour of chromosomes, are all of great importance and intense interest ; but, to use the illustration already employed, they no more account for the well-nigh miraculous process by which the original germ-cell becomes at last the fully developed individual with all its elaborately arranged tissues, organs, systems and groups of systems, than do the various pigments displayed on the artist's palette account for the finished picture. If, then, in our search for an explanation we have hitherto met with but

meagre success, the conclusion would seem to be that there must be certain other elements in connection with the problem, and possibly a whole side of things, which we have left altogether out of the reckoning.¹

Additional Note.—According to Conklin, the yolk-granules in the egg of the Ascidian (*Cynthia partita*) are of two kinds, some being yellow and the others slaty blue. After the entrance of the spermatozoon they shift their positions in the egg, and in such a manner as that, when segmentation takes place, the slaty blue material passes into the endoderm and the yellow material into the mesoderm. The ectoderm is formed out of transparent material previously discharged from the nucleus.

¹ T. H. Morgan himself says: "The cause of the differentiation of the cells of the embryo is not explained on the Factorial Hypothesis of heredity."—*Mechanism of Mendelian Inheritance*, p. 226.

Again, Jenkinson says: "Should the mechanical explanation prove to be scientifically insufficient, it may be necessary, with Driesch and the neovitalists, to invoke a consciousness of the end to be realised to guide and govern the merely material elements."—*Experimental Embryology*, p. 20.

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CHAPTER XXI

A FRESH DEPARTURE

It may have seemed perhaps scarcely worth while to have devoted so much space to the matters discussed in the last few chapters, if the conclusion finally reached was to be of so negative a character. But in view of the main purpose with which this book is written, it is precisely its negative character which is the important thing.¹ For the failure of every attempt hitherto made to solve the mystery of embryonic development along purely mechanistic lines, naturally inclines us to cast about in other directions, to see if we can find some new way in which the entire subject may be approached.

One thing is quite certain. It is that the whole of that immense body of gradually accumulated knowledge which we include under the term "natural science," has been acquired through one set of channels alone, viz. our bodily senses. From no other source have we derived the data on which our conclusions in reference to the external world have been based. And yet how apt we are to overlook the fact that these bodily senses of ours not only are very restricted both in number and in range, but render us reports which are always more or less commingled with elements which we have contributed out of our own mental store.

To take the last point first. To the ordinary unsophisticated individual, the so-called "man in the street," the colours which he sees, or rather *thinks* that he sees, in the objects around him do actually inhere in them. The sky

¹ "To work an hypothesis for all it is worth is the real and often the only way to prove its insufficiency."—William James, *Textbook of Psychology*, p. 6.

is blue, the woods are green, the poppies growing in the cornfields are really red; and should you venture to cast any doubt upon the subject, he will receive your suggestion with a look of blank incredulity. Yet few facts are better established than that all colours are of the nature of subjective effects. Light *objectively* regarded consists simply of waves of extreme minuteness propagated through the ether with enormous velocity. According to the source from which they come, they vary in length from about the $\frac{1}{31,000}$ th to the $\frac{1}{65,000}$ th of an inch. But as to why the longest of them on reaching the retina should set up nervous currents which are presently interpreted in the brain as red, whereas, if they had been the shortest, they would have set up currents which would have been interpreted as violet—as to why these two very dissimilar effects should be produced, we are left completely in the dark; nor does there seem to be any reason why the said effects should not have been exactly the reverse. But what is true of red and violet is true also of all the other colours in the spectral series. We are unable to trace the slightest connection between their very marked qualitative differences as they affect our consciousness, and those differences in mere wavelength which, as far as we know, are all that objectively distinguish them from one another. We gather, therefore, that the external world is not, strictly speaking, a coloured world at all; the colours which we attribute to it are the result of our own mental activity. Similarly, the other so-called “secondary qualities,” which we imagine to exist in the things around us, are of a subjective order—a remark which applies to all the infinite scents and sounds of nature. They are likewise effects which are somehow wrought in us by the external world, but the peculiar characteristics of which we ourselves confer on them.

Thus we see that the *prima facie* evidence of our senses can scarcely be relied upon to supply us straight away with more than very imperfect notions as to the true nature of the physical world around us. And it might well be the case that even if our organs of sense were assisted with all manner of the most improved instrumental means, they

would still be unable to put us in touch with the underlying reality of those external objects and events, about which we are sometimes prone to think that we know so much.

Again, our senses are very limited in number. It is true that, in addition to the usually recognised five, we possess a few others, like the muscular sense and the sense of temperature. At the same time, as for instance in the case of taste and smell, the amount of information which some of them convey to us is from the theoretic point of view almost negligible, whereas on the other hand nearly the whole of our ordered knowledge of the external world has reached us through one sense only, viz. the sense of sight. Astronomy, for example, is wholly dependent upon it. We should not know of the existence even of the heavenly bodies, and still less anything about their distances, movements, masses, etc., and about the gigantic scale on which the Universe has been constructed, if in the course of evolution we had not been provided with eyes. So, too, apart from our eyes we should have remained in blissful ignorance of all that the microscope has revealed as to the intimate nature of animal and vegetable cells, and of those wonderful processes connected with their growth, division and differentiation, as briefly set forth in the foregoing chapters. But it is, of course, impossible to say what might have been the vast additions to our knowledge on these and on numberless other subjects if only we had been endowed, say, with five hundred senses, instead of with just the few which are all that we now possess.

Again, the range of our senses is exceedingly limited, and particularly so in the case of the most important of them all, the sense of sight. Thus if the waves propagated through the ether are to awaken in us the sensation of light, their length—*i.e.* as measured from crest to crest—must keep within the somewhat narrow limits mentioned above. If they are longer than the $\frac{1}{31,000}$ th of an inch, they may affect us perhaps as heat; if they are shorter than the $\frac{1}{65,000}$ th of an inch, they may darken a strip of photographically prepared paper; but in neither case will they make any im-

pression on us through our visual organs. Hence, although to say so may seem almost a contradiction in terms, the greater part of what may be objectively described as "light" is quite invisible to us.¹ Evolution has conferred upon us the power of directly perceiving what is really but a very small fraction of it. It is as though in the case of sound, which consists of waves propagated through the air, we could hear only the notes belonging to about a single octave. G. Ellery Hall states, indeed, in his *Beyond the Milky Way* (p. 45), that there are at least 54 octaves of invisible light, as against the 1 octave which alone renders itself visible, while Professor J. Arthur Thomson puts the number of them at 62 (see *John o' London's Weekly*, September 10, 1927).

If, then, our senses are so limited both in number and in range, if the impressions which they convey to us of the outer world cannot be taken altogether at their face value, and if, moreover, they were primarily evolved simply that we might find for ourselves food and shelter—what warrant have we for supposing that they will enable us to get at the real, the inmost nature of the various objects around us? Or, again, what warrant have we for supposing that at some future time this may be possible when the instruments employed in observation will have become perhaps practically perfect? Imagine, for example, a microscope to be invented through which we could watch not only the dance of molecules and atoms, but the far swifter movements of the electrons within the atoms;² how could we be sure that even then we had got down to the ultimate reality of the so-called physical Universe, and had arrived at a complete understanding of what at bottom it actually is? All that such a microscope could do would be, by manipulating rays of light in a certain new way, to produce in us once more a number of visual sensations—sensations, however, of essentially the same nature as those which we have all along experienced.

Hence it may well be, in reference to those impressions which we receive through our senses of external objects

¹ Silvanus Thompson, *Light Visible and Invisible*.

² Bertrand Russell, *The ABC of Atoms*, and J. Mills, *Within the Atom*.

and events, that we are very much in the same position as a native from the wilds of Central Africa who, on seeing a watch or a clock for the first time, should try from mere outside inspection to give an account of its internal construction and to explain what it was that was causing its hands to go round.

The annexed diagram will help perhaps to make clear what has just been said. Here A stands for some external object as it is in itself, a for that portion or aspect of it the knowledge of which is conveyed to us by our senses, and b for those secondary qualities—colour, sound, taste and smell—which are due to our own mental activity. Then, whereas “the man in the street” will unreflectingly identify

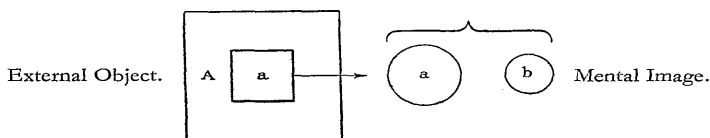


FIG. 46.

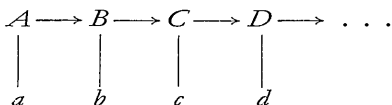
the object with $a+b$, and the thoroughgoing materialist will identify it simply with a , a truer philosophy will lead to the identification of it with A , of which a forms only an aspect or part.

Let, now, the capital letters A, B, C, D , etc. represent a sequence of events standing in causal relation to one another, A being the cause of B , B the cause of C , and so on; and let the smaller letters a, b, c, d , etc. represent the same events, but only in so far as they are at present, or may be at some future time, apprehended by our bodily senses. Now in regard to such a sequence, provided that it belongs to the purely inorganic sphere, there is generally no need felt to go behind the sense appearances in order to explain it, for each perceived event—or rather “event as perceived”—apparently contains within itself all that is necessary to account for the one immediately following it. Hence the sequence may be represented thus :

$$a \longrightarrow b \longrightarrow c \longrightarrow d \longrightarrow \dots$$

in which the arrows are intended to indicate the successive causal links. In many instances, indeed, when once the law governing such a sequence has been ascertained, it becomes possible to predict events lying far ahead in the future. Of this we get the best illustration in the calculations of astronomers in reference to eclipses, occultations, the return of comets and other celestial phenomena.

When, however, we pass from the purely inorganic sphere to the sphere of living things, there is at once felt to be a difference. The sequences have now to a large extent changed their character. Especially is this so in the case of what I will venture to call "the standing miracle of the Universe," viz. that marvellous series of events which, beginning with the comparatively simple germ-cell, ends in the highly complicated, fully developed adult organism.¹ Here, as we have seen in the preceding chapters, it is quite impossible to explain from the information reaching us through our senses why the events should follow one another in the way they do. Natural science, the further she has pushed her inquiries in this direction—and of course in so doing she has been perfectly within her right—seems to have got no nearer to any real solution of the problem, although along her path she has made some of the most important and highly interesting discoveries. The fact is, the formula given above does not serve us in this case, and hence I would suggest the following as a substitute for it:—



in which the causal links are no longer seen connecting together *a*, *b*, *c* and *d*, the outward appearances, but rather those underlying realities *A*, *B*, *C* and *D*, of which they form simply a part.²

¹ "The development of a fertilised egg-cell remains to us one of the wonders of the world."—J. A. Thomson, *The System of Animate Nature*, p. 94.

² "The present moment of a living body does not find its explanation in the moment immediately before."—Bergson, *Creative Evolution*, p. 21.

To recur to the illustration of the man who had never before seen a clock—from his observing that it only struck when the long hand was pointing to twelve, he might be led to infer that that particular position of the hand was somehow the cause of the striking, whereas if he had been allowed to examine the clock's inside, he would have discovered that both the position of the hand and the striking were caused by the movements of the wheels, and that these in their turn were dependent on the pendulum and the weights. And somewhat similar to this, I would submit, is the relation in which we stand to the facts of embryonic development, when on the strength of our observations we attempt, but with such indifferent success, to give a purely mechanistic explanation of them. A still better illustration perhaps is afforded by the cinema. A spectator who had never been to an exhibition of the kind before might be disposed to think that the rapidly succeeding pictures thrown upon the screen were causally related to one another, each being produced by the one immediately preceding it, whereas the events forming the true causal chain were taking place all the time inside the lantern at the back of the hall. In fact, the vice of materialism appears to consist of the following quite gratuitous assumption: *That, if only we were equipped with adequate instrumental means, the Universe, as presented at any instant to our extremely limited bodily senses, would enable us to foretell all its future states.*

Considerations of this kind must seem, however, to hang very much in the air, besides being eminently unfruitful, so long as we are unprovided with any clue as to the source of the realities underlying the appearances which our senses present. The question, therefore, becomes important: Does such a clue anywhere exist? Can we find in the external Universe any material objects or structures, associated with which are certain very real properties and powers that by their essential nature lie altogether outside the range of our bodily perceptions?

The answer to this question is not far to seek. Such structures are to be found in those exceedingly complicated masses of nervous tissue which form the cortex or outer

coating of the human brain ; for here in some mysterious manner consciousness has its seat, and we find feelings, memories, trains of ideas, processes of reasoning, emotional states and volitions, all of which must for ever remain inapprehensible by our senses. Even if after the removal of a portion of a man's skull we could watch with a microscope, like the one imagined just now, the actual movements of the molecules and the atoms, etc., composing his brain, we know very well that it would not bring us one whit nearer to perceiving what was mentally taking place within him. Nor would the experiment be any the more successful, if with the help of such a microscope and of some suitable arrangement of mirrors, the man himself could watch the said movements with his own eyes.¹

Or leaving the higher faculties of the mind on one side, let us fix attention on the sensations. If we gaze at some distant source of what is commonly called red light—as for instance the planet Mars—the redness which we perceive is not really in Mars, but, as was explained just now, in ourselves ;² not in our brain-cells, however, for they remain of the same colour whatever we may happen to be gazing at, but in the conscious state which somehow for the time being stands in such mysterious relation to them. Moreover, inasmuch as light, of whatever colour or rather wavelength it may be, never gets the least fraction of an inch behind the retina, but is transformed there into nervous currents which on reaching certain cells in the occipital region of the brain produce in us the *sensation* of colour—though the cells themselves are immersed in total darkness, the darkness of the interior of the skull—it will again be evident how impossible it is to arrive by means of our sense organs at that which constitutes the inner reality of these cells.

But now arises the question, How did these highly favoured cells composing the cortex of the brain come by their inner reality, acquire this their peculiar psychic

¹ C. A. Strong, *Why the Mind has a Body*, pp. 336-340.

² See some admirable remarks on this subject in Stephen Paget's *I Wonder*.

character? They are, as we have seen,¹ the final result of the repeated subdivisions of certain cells which at an early stage in our embryonic development were folded off from the rest of the ectoderm to form the neural tube, all these cells in their turn having been derived by similar subdivisions from the one original germ-cell. Hence, if the law of continuity is to hold, we seem compelled to attribute something of a psychic character, however vague and at present ill-defined, to *all* the cells just referred to, including of course the germ-cell itself.² And we feel all the more justified in doing so because, as is generally allowed, mental peculiarities can be inherited as well as physical ones³—a thing which apparently could not happen, unless those mental peculiarities were somehow transmitted through the germ-cell from one generation to the next. Also, the germ-cell must be held responsible for the handing on of the various instinctive feelings, like those of hunger and sex, which possess a mental as well as a physical side.

But to pursue the subject still further. How did the germ-cell, and how did the spermatozoon and the ovum, which by their union produced it, acquire in the first instance their psychic character? Obviously they can only have acquired it from the pre-existing germ-cells of the parents, and presumably—if we follow Weismann—by transmission through those special sets of cells which in both the father and the mother constituted the germ-track.⁴ Thus we are led to attribute a certain psychic character to at least *two* tracks of cells in the body, viz. to the track terminating in the cells of the cerebral cortex

¹ See Chapters XV and XVI.

² "It may be that the germ-cell has also its analogue of mind—a not unreasonable hypothesis, since it develops into a creature with a mind."—J. A. Thomson, *The System of Animate Nature*, p. 517. Also William McDougall, *Body and Mind*, p. 116. He says: "The Principle of Continuity and the analogy presented by the unicellular animals, each of which divides repeatedly into two or more cells that lead independent lives, seem to compel us to suppose that the germ-cell not only has life, but also mind, that it enjoys psychical life, in however lowly a manner or degree, and that on the division of the germ-cell each of the cells derived from it has also its psychical capacities."

³ R. H. Lock, *Variation, Heredity and Evolution*, pp. 110-112, and F. Galton, *Hereditary Genius*.

⁴ See Chapter XVIII, p. 246.

and to the track terminating in the reproductive cells, the spermatozoa and the ova. The annexed diagram is intended to illustrate this, in which the small circles stand for the cells as they are successively produced in the bodies of a mother and her offspring, those filled in with black indicating the cells belonging to the two tracks in question.

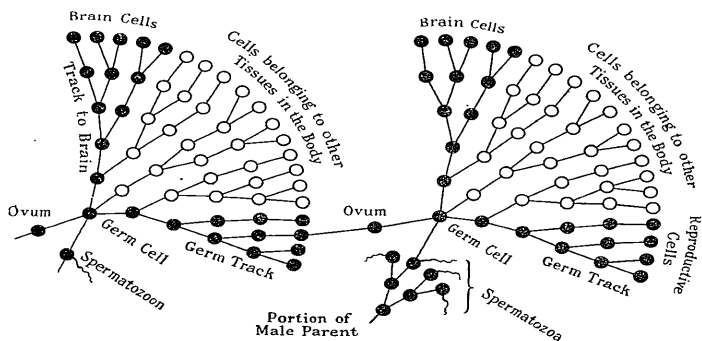


FIG. 47.

Such a diagram, however, almost certainly needs correction. Seeing that *all* the cells in the body, not merely those belonging to these two tracks, are descended from the germ-cell, it seems far more reasonable to suppose that they *all* more or less partake of a psychic character. Hence in the diagram *each* of the small circles should be filled in with black.

Again, the theory, as I have just outlined it, can scarcely be regarded as expressing even now the real truth of the matter. Because all the higher organisms, man included, are built up of myriads of cells, it does not follow from this their multicellular constitution that they are necessarily poly-psychic.¹ Not only is it much simpler to think of each entire organism as possessed of a single "psyche"—a term to which I shall try to give greater precision presently

¹ E. B. Wilson says of the cells: "They are local centres of a formative power pervading the growing mass as a whole."—*The Cell in Development and Inheritance*, p. 59.

—but there appear to be several very good reasons why we should do so.

1. In the first place the significance to be attached to the multicellular structure of the higher organisms is apt to be exaggerated. It has been conceived of almost as though such organisms were the result of the coming together of a number of originally independent parts. But we know from embryology that this is not so. It is unity, as represented by the solitary germ-cell, which gives rise to multiplicity, not multiplicity to unity; and hence of the two it is the unity which is the essentially fundamental thing. De Bary, the great German botanist, once wrote: "It is not the cells which make the plant; it is rather the plant which makes the cells . . . it is not so much like adding brick to brick, as like dividing a growing bulk into convenient areas."

2. Again, it has been shown that in many instances the cells of a multicellular organism are not so entirely shut off from one another as was at one time supposed. Even in a plant, where the cell-walls are frequently of considerable thickness, delicate protoplasmic filaments have been detected passing through the walls and thus rendering the living substance throughout the plant practically continuous.¹ This is conspicuously so in the case of the *Sieve-tubes*, which in all the higher forms constitute the most important element of the *Bast*—that ring of tissue almost immediately surrounding the wood. It is not surprising, therefore, that the same thing should have been found true in the case of many animal tissues,² for in animal tissues cell-walls are replaced by thin membranes, and the cells themselves have consequently been brought into much closer relations with one another. Then we have in both animals and plants what are known as *Canocytes*—cells, that is, if we may still describe them as such, in which the nucleus has gone on dividing, but in which the surrounding protoplasm has not been cut up into separate portions by subsequent planes of division,

¹ S. H. Vines, *Students' Textbook of Botany*, p. 91.

² E. B. Wilson, *The Cell in Development and Inheritance*, pp. 58-60; also E. S. Schäfer, *The Essentials of Histology*, p. 2.

with the result that once more we get continuity of substance. The argument then is, whatever it may be worth, that this continuity of living substance, as perceived by our outward senses, points to a something corresponding to it—a kind of unity—in that underlying reality which is unperceived and which is probably, so we have seen, of a psychic nature.

3. Another and much stronger argument may be based upon the fact that although the human cortex is composed of many millions of cells, there is only one consciousness associated with their activity.¹ There are not a number of separate centres of consciousness. When it happens that several of my sense organs have been simultaneously excited and nervous currents have travelled up in consequence to the various corresponding regions of my brain,² it is not the case that in one of these regions there is the consciousness of sight and in another the consciousness of hearing and so forth; on the contrary, the different sensations thus produced form the constituent elements of a single undivided conscious state. It is I who at one and the same time see, hear, touch and smell. Or take sight alone. There is every reason to believe, as will be explained in the next chapter, that to every point of the retina there practically corresponds a point, and possibly a separate cell, in the visual area at the back of the brain.³ Hence when the inverted image of some outside scene is projected upon the retina, not only are a vast number of retinal cells affected, but a vast number of cortical cells as well, the latter being thrown into various states of agitation according to the different colours and the different degrees of illumination of the several objects composing the landscape. The mind, however, being one and not many, combines all the multitude of impressions thus received into a single and harmonious picture. From this, then, and from other considerations of a similar kind we may fairly conclude that the "psyche," which we regard as somehow animating all the cells of the body, is also one and not many.

¹ Except perhaps in those abnormal cases of double personality (see *The Dissociation of a Personality*, by M. Prince).

² See Chapter XI and fig. 14, p. 128.

³ Chapter XXII and fig. 14, p. 128.

4. There is another important consideration. Much has been said and written in recent years about the "sub-conscious mind," supposed to be possessed by each of us. It has been described as "the seat of the emotions and the storehouse of memory,"¹ and has been thought to be much more closely related to the various organs of the body and to their several functions than the fully conscious mind, which is only in direct relation with the brain. Cures effected upon patients when in the hypnotic condition by means of suggestion are on this theory to be attributed to the circumstance that the conscious mind, being more or less in a state of abeyance, the subconscious mind is rendered more accessible to suggestive influences. If, then, the suggestion made should be to the effect that the diseased member is on its way to recovery or is in fact quite well, this in itself will tend to bring about the desired result, because of the aforesaid close relation of the subconscious mind to every part of the body.² Now granting that some such theory as this represents the truth—and it undoubtedly seems to offer an explanation of certain very remarkable facts—then we have only to identify this subconscious mind with the psyche as above described in order to obtain further confirmation of the theory that the latter is one, and not many.

In the above paragraphs I have purposely employed the term "psyche" in preference to any English equivalent, such as "the soul," because I wished to avoid the importation into it of any meaning not intended. "The soul," for instance, might be taken as *necessarily* implying consciousness of some sort, or as suggesting perhaps the idea of immortality. I would, therefore, for the present define the *Psyche* as that inner unseen Principle of Life which pervades the entire organism, controlling all its very varied activities, and which has been the secret cause of its development from the germ-cell onwards. I conceive of it as being in its essential nature akin to mind, although doubtless differing from the fully conscious mind in several important

¹ T. H. Hudson, *The Law of Psychic Phenomena*.

² See, amongst other works, *Suggestion and Auto-Suggestion*, by C. Baudouin.

particulars.¹ That it is, however, very closely related to the latter comes out in a number of ways, which I will now proceed to specify.

1. And, first, like the fully conscious mind, the psyche constructs.² True its constructions differ in many respects from our consciously carried-out constructions. With the latter there are generally two stages gone through, viz. first, a purely mental one in which we form a more or less accurate internal picture of the thing, whether piece of mechanism, work of art or whatever else it may be, which we wish to produce; and secondly, a stage in which we proceed to give it outward actuality. But with the psyche it is almost certainly the case that in its construction of the various organs of the body there is nothing corresponding to the first of these stages. It probably sets to work in much the same sort of unconscious or semi-conscious way in which every morning, for example, we go through the routine of dressing. Moreover, our ordinary constructions take the form of material arrangements external to the body, whereas the constructions of the psyche are for the most part internal and result in the body itself. Again, wonderful as is the constructive power of the conscious human intelligence, it is as nothing compared with the constructive power of the psyche, which in comparatively so short a space evolves out of a minute speck of protoplasm the many millions of cells which the body requires for its complete equipment, and at the same time differentiates them and builds them up into that infinitely elaborate arrangement of tissues, organs, systems and system-groups which were briefly described in Chapters VI to XII.

2. But the psyche not only constructs; its constructions,

¹ J. A. Thomson in his *Heredity* speaks of "the secret of life which many think will never be read until we recognise that it is also the secret of mind." Again, A. Dendy says in his *Outlines of Evolutionary Biology*, p. 11: "Chemists and physicists have helped us much towards a correct understanding of the living mechanism, but when they have done their best it may well be that the question, 'What is Life?' will remain unanswered, and that we may still have to take refuge in the idea of an unknown 'soul' to explain the difference between living and non-living things."

² "The soul . . . is that without which it" (the organism) "does not exist—that which vivifies and constructs or composes and informs the whole."—Sir Oliver Lodge, *Man and the Universe*, p. 79.

like those of the fully conscious mind, are all of a purposive character, and that in a twofold way. For the end aimed at—whether there be any consciousness attending it or not—is not simply a body perfect in all its parts and conforming to whatever may be its specific type—a merely static result—but a body, each of whose parts shall discharge a definite function and thereby accomplish a definite purpose. Moreover, as explained in Chapters VII to XII, in the discharge of these functions it often appears that something—we will not say at present exactly what—has been deliberately at work trying to solve a very difficult problem, though not always solving it in the same way. We have a good instance of this in the different methods employed in the bird and in the mammal respectively for supplying the growing embryo with the necessary food and oxygen.¹

3. This leads to another point of resemblance between the psyche and what we generally understand by mind. For not only does the fully developed body consist of a number of organs each having a purpose of its own, but these organs are co-ordinated into systems, and these systems into system-groups, and in such a manner as that each system and each system-group has again a purpose of its own.² But this implies a principle of unification akin to that which is so eminently characteristic of mind, and which enables it not only to combine in one and the same conscious state a number of different sensations, but to compare together different ideas and to build them up into complex wholes. Hence we may say of the psyche that, like the conscious mind, it constructs, it constructs with a purpose, and it exhibits in its constructions a most wonderful combining power.

4. Yet another notable resemblance is shown by the way in which the psyche will sometimes adjust itself to contingencies of an adverse character, as when, for example, having lost an important member it proceeds to grow another. Reference has already been made more than once to the regeneration of a lobster's claw and of the lens in a

¹ Chapter XV, pp. 195-202.

² See Chapter XII.

newt's eye,¹ performances both of which it seems impossible to explain along mechanistic lines. The same may be said of the remarkable manner in which a frog's embryo will right itself and continue to develop normally, in spite of the fact that its cells have been subjected to artificial pressure and forced thereby into quite different positions with respect to one another.² But this power displayed by the psyche in its effort to overcome unforeseen obstacles and to carry out, so to speak, its original, although perhaps unconscious intention, is the very image of what with our fully conscious minds we are constantly doing when, having failed to accomplish our purpose along one line of action, we have recourse to another.

5. Lastly, like the fully conscious mind the psyche would appear to be possessed of a kind of memory³ which, while the development of the individual proceeds, causes the various stages in it to be a more or less exact repetition of those which were passed through by the parents during their development. This implies, of course, that, like all the other powers of the psyche, this memory is somehow transmitted through the solitary germ-cell—an idea which by many no doubt will be objected to on the score that memory, such as we actually know it, is dependent upon certain more or less permanent impressions of a physical kind which have been made, not upon a single cell, but upon a vast number of them situated in the brain. But this raises a question of such paramount importance in reference to my general argument that I must postpone its consideration to the next chapter.

What I have endeavoured, then, to show in the preceding paragraphs is that, if, in order to account for the development of the individual, we postulate in it the existence of an invisible entity which we will agree to call its "psyche," then this entity does in the most extraordinary manner exhibit in its behaviour powers and qualities closely resembling those of the fully conscious mind. And inasmuch as all attempts to explain individual development along

¹ Chapter II, p. 13.

² Chapter XVIII, p. 255.

³ E. Hering, *On Memory*, and Samuel Butler, *Unconscious Memory*.

purely mechanistic lines have been shown to fail, we seem driven to adopt some such theory as the one sketched above. In this, be it observed, we are not presupposing the existence of something utterly unknown, but of something which corresponds to what we have discovered in our own inner experience.

In conclusion, granting that the above theory, or one not very dissimilar to it, should ultimately turn out to be true, then there are certain corollaries which seem necessarily to flow from it.

1. First, we are constrained to believe in the existence of a psyche—in the sense which I have tried to indicate—not only in every human being, but in every organism down even to the lowest.¹ The law of continuity obliges us to do so, and, besides, the development of every form of life stands just as much in need of explanation as our own. Also, the theory must be extended to plants as well as to animals, for like animals every plant starts as a tiny piece of protoplasm, a single cell, which by its continual subdivisions and differentiations is gradually transformed into the fully mature individual.²

2. Again, we must suppose that whenever an organism is forming its reproductive cells, whether spermatozoa or ova, pollen-grains or oospheres, there is, alongside of the purely physical act of division, a division also of the psyche—a separating off of certain portions of it—and in such a manner as that in each of these portions there comes to be a psyche which in all essential respects resembles the one from which it has been derived, and which is charged, therefore, with the same stock of accumulated memories.³ Also, when the male and female reproductive cells unite, as

¹ "All living things must possess some rudiment of soul."—Sir Oliver Lodge, *Man and the Universe*, p. 79.

² "We know that plants are able to do many things that can only be accounted for by ascribing to them a 'psyche,' and yet they possess no central organ comparable to the brain, no highly specialised system for intercommunication like our nerve trunks and fibres."—Marcus Hartog, *Problems of Life and Reproduction*, p. 260.

³ On the psychological hypothesis some such division must necessarily take place when, after the separation of the two first daughter-cells produced by the segmentation of a frog's ovum, each of them develops into a complete embryo (see Chapter XVIII).

in the act of fertilisation, there must be a coming together and a complete blending of their two psyches.

Additional Note.—Looking at the subject from a more philosophic point of view, we ought not perhaps to draw too sharp a distinction between the psyche and that material form, the body, which we have supposed it to pervade and actuate. What we call the body may after all be the psyche itself, or rather that particular aspect of it which in so vivid a manner presents itself to our senses. Again, the similarity in the constitution of the nuclear material in all the cells of the body may be simply the visible expression of the fact that the invisible reality underlying them is in every part of the body one and the same. If this be so, then the chromosomes may no longer perhaps be regarded as being in themselves the bearers of the hereditary characters, but rather as the material symbols of what after all inheres in the psyche itself. Or we may put the same thing in another way and say, of all the many cells in the body, that their identical nature, as regards the number and constitution of their chromosomes, may be due to the fact that they are just so many multiple presentations to our senses of the same fundamental reality. What we outwardly observe may be compared to the appearance of some familiar object as seen through a glass of many facets.

CHAPTER XXII

MEMORY

IF, as explained in the preceding chapter, the underlying unperceived reality which controls the development of every living thing is of an essentially psychical nature, as it would seem to be from the several ways in which it resembles in its working a fully conscious mind, then perhaps the most important thing about it is its apparent possession of a faculty which is akin to memory, if not actually identical with it. On this account a digression on the general subject of memory would seem desirable at this point, and especially if, as we shall see, it tends to add precision to our ideas and to confirm some of the conclusions to which we have already come.

Now for a complete act of memory four things are generally acknowledged as being necessary :

1. First, there must be the original experience, of whatever sort it may be and whenever it may have occurred, which is afterwards recalled to mind.

2. Secondly, there must be the revival of the experience, though not as it at first presented itself, but in the far less vivid form of a mental image or idea.

3. Thirdly, to account for this revival, the original impression must by some means or another have been preserved.

4. And fourthly, for the act of memory to be quite complete, the revived image must be recognised as representing something which was once actually perceived.

Leaving the other points on one side, let us concentrate attention on the third of them, viz. on that remarkable power which we possess of *apparently* storing up in some subconscious region of the mind our past experiences—all the knowledge which we have acquired during perhaps a

fairly long life. Cases are continually occurring in which a man, after an absence, say, of forty or fifty years, revisits the scenes of his childhood, and one by one a whole host of memories crop up which might be supposed long ago to have perished. Or, to quote an instance for which I can personally vouch, the peculiar sound of a falling bolt attached to a particular door was felt to be perfectly familiar after the lapse of thirty-nine and a half years, although during the whole of that period the experience had never been renewed or even thought of.

The question then is, How is this apparent storage of our memories effected? What becomes of them during those intervals in which never once do they obtrude themselves on our consciousness?

The theory which in recent times has received perhaps most favour is that during these intervals our memories *as such* cease to have any existence. The original experiences left certain traces on particular cells or groups of cells in the brain, and the result is, that when on some after occasion these cells are again stirred into activity by nervous currents passing through them, the said memories are automatically revived.¹ In other words, what happens closely resembles what happens in the case of an ordinary gramophone. The sounds of a piece of music, as it was once played, have long since died away, but they have left their marks or impressions on a revolving disc of shellac, and now, when the disc is again made to revolve in the appropriate instrument, the sounds are all reproduced and in their right consecutive order. Now our memories, it is said, are reproduced in much the same way, but they no more have any existence during those times when we are unconscious of them, than have the sounds of the piece of music before the disc is put into the gramophone and the latter is wound up and set going.

It belongs also to the above "materialistic theory"—if I may call it so—that it generally seeks to account for the *association* of our ideas by means of the nerve-fibres—axons,

¹ That they are the same cells which are stirred into activity, see William James, *Principles of Psychology*, pp. 72, 73, 122, 123.

collaterals, dendrons, etc.¹—which serve to connect up the different cells of the cortex and to give free passage to the nervous currents. The tendency of the latter to pursue certain paths in preference to others is supposed to depend upon associations and habits which have been previously established and which have rendered such paths specially permeable. In this way idea *A*, for example, will call up idea *B*, and similarly long trains of ideas will often be set in motion.

Before venturing to offer any criticism on the above theory it is only right to state some of the chief arguments which have been adduced in support of it.

1. First, there are the well-known effects of anæsthetics. Chloroform, ether and nitrous oxide, by their chemical action on the substance of the brain, completely obliterate consciousness—at all events for a time—and apparently along with it all our memories.

2. Secondly, a violent blow on the head will do the same.

3. Thirdly, with the approach of old age there is often considerable difficulty in recalling memories, especially the memory of names. This is presumably due to a certain stiffening of the brain tissues.

4. Fourthly, as previously explained, in order that we may see, it is not enough that an image of the external landscape should be thrown upon our retinas; it is essential that the nervous currents there set up should be conveyed to the cortical cells at the back of the brain which form the so-called visual area.² Now it is found that, if at any point along this line of communication a blockage should occur, as the result of disease or from any other cause, blindness will ensue, but that the patient will still be able to picture to himself the scenes with which he was formerly familiar and to revisit them occasionally in his dreams. If, however, the said “area” should itself become diseased, not only will he become blind, but he will lose all his visual memories, and will cease even in his dreams to imagine that he sees things.³ And this certainly would *appear* to point to the

¹ See Chapter XI, p. 131.

² See Chapter XI, pp. 128, 132.

³ William James, *Textbook of Psychology*, p. 112.

conclusion that our memories—or, if you will, the peculiar physical conditions which lead to their revival—are somehow lodged in the brain-cells.

5. Lastly, the same conclusion is suggested and apparently rendered probable by the way in which, as already said, the brain-cells are connected up with one another by means of the nerve-fibres; for such an arrangement would seem to provide just the sort of mechanism which is needed to account for the association of our ideas.

In spite, however, of these considerations, which of course every theory of memory must take into proper account, it appears to me that, so far as the storage or *retention* of our ideas is concerned, the brain-cells have little, if anything, to do with it; it is a function of the mind rather than of the body. Although the brain is almost certainly called into action whenever our ideas are *revived*, the same sets of cells again being agitated as were agitated by the original experiences, this is no more due, I contend, to changes wrought by those experiences in the substance of the brain, than is the repetition of a tune on the piano due to changes produced in the piano-strings, when the tune was originally played upon it.¹ My reasons for thinking so I must now endeavour to explain.

It is stated by Dr Halliburton in his *Handbook of Physiology* (p. 736) that "there are subdivisions of the visual cortical area which correspond to different regions of the retina"; and he adds: "We may, in fact, speak of the visuo-sensory field in the cortex as the *Cortical Retina*, upon which the impulses from the actual retina in the eye are projected in a manner analogous to the way in which the field of vision is projected upon the actual retina."

Now, for reasons which will presently appear, it is hardly possible to exaggerate the importance of this conception; only, first, let us be quite sure that we clearly understand what is meant by the "cortical retina," and what are the grounds on which belief in it rests. In Chapter X

¹ "The casual way in which most writers on these topics speak of brain-traces and memory-cells and so forth, without making any attempt to conceive the nature of these assumed traces, is to my mind astonishing."—William McDougall, *Body and Mind*, p. 332.

we saw that, in consequence of the interposition of the crystalline lens, the rays of light which enter the eye are sorted out in such a manner as that, when they reach the retina, every point in the latter corresponds for the time being in colour and in degree of illumination to some point in the external scene. Further, the spatial relations of the one set of points correspond to the spatial relations of the other set, with the result that a definite picture of the external scene, though an inverted one, is thrown upon the retina, or, to speak more exactly, on the layer of the rods and cones. But from the layer of the rods and cones there proceed in each eye no fewer than about half a million nerve-fibres, through which the nerve-currents pass on their way to the two closely adjoining visual areas at the back of the brain, one in each of the cerebral hemispheres. Now on *a priori* grounds it would seem highly improbable that these currents should all be exactly alike, coming as they do from points in the retina differently affected by the rays of light ; and besides, if this were so, the sorting out of the rays by the lens would have been apparently to no purpose. We conclude, therefore, that the various currents must differ from one another both quantitatively and qualitatively, and, further, that when they reach one of the said visual areas they must affect different portions of it differently, and presumably in such a manner, as that once more there is a correspondence of a spatial kind between the cells composing the area and the various points of the retina. Again, this being so, there will be a correspondence also between these cells and the various points of the external scene.

The following considerations bear out this conclusion :—

1. As the accompanying diagram will show, in man and in all other animals possessing *stereoscopic* vision¹ the nerve-fibres proceeding from the inner half of each retina—the half nearer the nose—cross over in the optic chiasma to the opposite side, whereas those from the other or outer half do not cross over. Now it is found that if disease of the

¹ In stereoscopic vision the pictures produced on the two retinas are very nearly, though not quite, identical ; each takes in practically the whole of the external scene. In panoramic vision the pictures are not identical ; each takes in only half of the external scene.

fibres occurs in *g*, the optic tract, this does not cause blindness of the eye as a whole—as it would have done if the disease had occurred in *e*, the optic nerve—but it causes

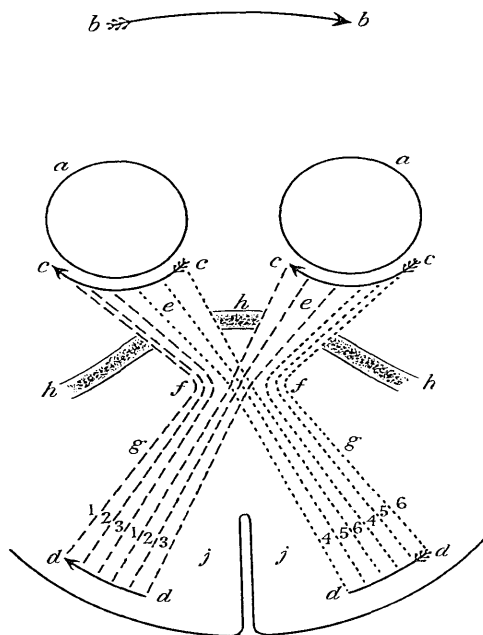


FIG. 48.—STEREOSCOPIC VISION.

a, a, Eyeballs; *b*, External scene or object; *c, c*, Retinal images; *d, d*, Cortical images; *e, e*, Optic nerves; *f*, Optic chiasma; *g, g*, Optic tracts; *h, h*, bone at base of skull-box; *j, j*, Hinder parts of the cerebral hemispheres. Diagrammatic and not quite correct, as probably fibres 1 and 1 run to the same point in cortex. So, too, with 2 and 2, etc.

blindness of the corresponding *halves of both the eyes*, a condition of things known as *Hemianopsia*. But this naturally results from the peculiar arrangement of the nerve-fibres, and shows that one-half of the external scene must in some sort be pictured on one side of the brain and the other half

on the other side, and that to that extent at all events there must be some sort of spatial correspondence such as the above theory supposes.

2. In animals, however, like the guinea-pig and the rabbit,

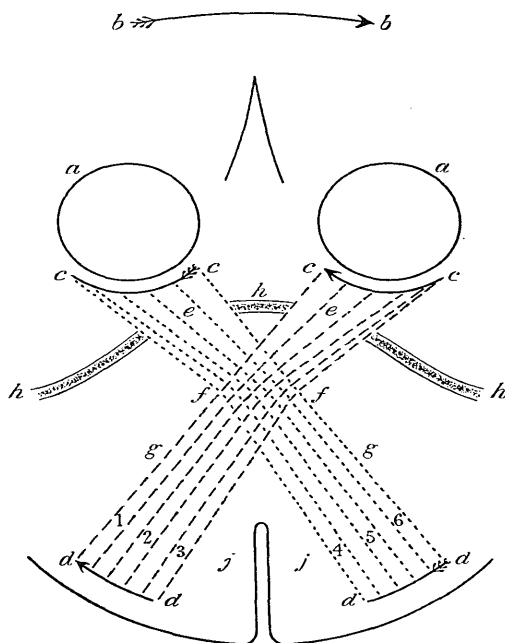


FIG. 49.—PANORAMIC VISION.

Same lettering as in fig. 48. Observe in this and in the previous diagram how, as the result of the crossing of the fibres, the two cortical images are brought into right relation with each other.

which possess only *panoramic* vision, it is found that practically all the fibres cross over in the chiasma,¹ with the result that again the perception of the two different sides of the external scene must be effected by the two different

¹ F. W. Mott, *The Progressive Evolution of the Structure and Functions of the Visual Cortex in Mammalia*.

sides of the brain. Moreover—and the point is extremely interesting—inasmuch as the image formed on each retina is not only inverted but turned about,¹ so that the right side has become the left and the left the right, it follows that if it were not for the *complete* crossing over of the fibres in these animals, the right and left cortical images would not be properly adjusted to each other along the central line. This furnishes another piece of evidence which the second diagram is intended to illustrate.

3. Another argument may be based on the analogy which is presented by the spatial arrangement of the several motor areas in the brain in front of the great fissure of Rolando. It will be seen on reference to fig. 14 that this arrangement when inverted corresponds roughly to the spatial arrangement of the several parts of the body to which these areas supply nerves. We may reasonably conclude, therefore, that there exists a similar correspondence between the cells forming the visual area of the cortex and the cells forming the layer of the rods and cones at the back of the eye.²

Assuming, then, the existence of a cortical retina in the sense above defined, let us see what bearing it has on the question of our visual memories—that is, on the retention of the mental images of persons, places and things which we have at any time seen in the past. Suppose we fix our gaze on almost any external object, except perhaps a star, which is practically a mathematical point, it will be evident that, instead of *one cell only* being affected in the cortical retina, there will be *several hundreds and even thousands of them*, their exact number depending partly on the actual size of the object and partly on its distance from the eye. Or consider the case of a child who may never have seen any wild animals before or even pictures of them, but who is taken one day to the Zoological Gardens and is shown for the first time lions and tigers, elephants and camels, giraffes and zebras, etc. As he looks at each of them in turn,

¹ See Chapter X, p. 107.

² See also reference to certain experiments by Schäfer and Munk on p. 110 of William James's *Textbook of Psychology*, and to remarks of Meynert on p. 105.

thousands of the cells in the visual area of his brain will be thrown into a state of excitement, and, *what is more, the successive sets of cells thus affected will be by no means entirely different sets. On the contrary, each set will contain a number of cells which are common to many, if not to most, of the other sets.* In other words, there will be a considerable amount of overlapping, like the overlapping of images which would be produced if the same photographic plate were exposed to a succession of different scenes. Yet this child, if he happens to have any talent for drawing, will be able on his return home to draw from memory the various animals which he has seen, and to draw each of them—the lion with his mane, the elephant with his trunk, the camel with his hump, the giraffe with his long neck, and the tiger and the zebra with their stripes—without in the least confusing them with one another. The question is, however, How is he able to keep these memories of the various animals which he has seen distinct from one another, if his power of doing so is dependent on a number of superimposed sets of impressions of a purely physical kind made upon the cells of his brain? In his attempt to draw these animals we should have expected him to produce a perfect hotch-potch instead.

But a case like this is simplicity itself compared with that of a grown-up person whose mind is stocked with all the innumerable memories which are the result of the pouring in upon him, during the whole of his past life, of an incessant stream of visual experiences. How is it possible for him on the hypothesis which I am criticising to isolate any one of these memories from the rest, and to make it stand out sharp and clear in his consciousness? Or, in the instance quoted above, how was it that the memory of the sound of the falling bolt, if stored up by means of certain physical impressions made on the cells of the auditory area, should not have been confused with, if not entirely swamped by, all the memories of the other sounds which had since been heard during the long interval of thirty-nine and a half years?

Of course it would be a very different matter, if the

impression left by each of our visual experiences could be thought of as located in a single brain-cell or in a comparatively limited number of such cells; the difficulty arises when it is known that for every one of these experiences hundreds and perhaps thousands of cells are called into requisition. For this necessarily involves an overlapping of the kind referred to above, and the utilisation of the same cells over and over again a myriad times, both in the formation and in the reproduction of the memories in question.

Again, if we could confine, so to speak, each visual memory to a single cell, it would be possible perhaps to show how the revival of one such memory might lead to the revival of another. We should simply have to suppose that the nervous excitement set up in one cell was transmitted to another through a single communicating fibre—that is to say, either through the axon of the first cell or through one of its collaterals, the terminations of which arborised round the second cell.¹ But when to each of these memories there correspond, as we have seen, not merely one or a few, but perhaps hundreds and even thousands of cells, then in the case of each associative link an equally numerous set of fibres would seem to be required for the nervous excitement to be safely passed on from the one set of cells to the other. Moreover, seeing that during a long life a countless multitude of associative links of this kind must be formed, we are compelled, arguing along these lines, to multiply the fibres to such a prodigious extent, as to render it extremely doubtful whether the brain can contain a sufficient number of them for the execution of the task.

But there are several other difficulties with which the theory in question is confronted.

1. And, first, in most cases a visual image becomes associated not only with one, but with several, and often with a considerable number of other images, each of which it will tend to revive. Thus the thought of a particular individual may suggest to me the place where we last met,

¹ See Chapter XI and fig. 14.

or the letter which I received from him a month ago but have not yet answered, or it may make me think of a relative of his with whom I am much better acquainted, or of some other third person whom he very closely resembles, and so on *ad infinitum*. But if for each of these associative links we are to assume a special set of communicating fibres running perhaps into many hundreds and thousands, consider how the complications, surely great enough already, would have to be indefinitely multiplied.

2. Or to revert to the child who has just returned from his visit to the Zoological Gardens, what particular set of cells are we to think of as thrown into a state of excitement when he calls to mind, for example, the elephant? As likely as not he saw the animal perambulating the grounds, in which case a whole series of pictures of it, all more or less overlapping one another, must have been cast on the rods and cones at the back of his eye, and must therefore have successively affected a number of different, and at the same time more or less overlapping, sets of cells in his cortex. Again, he probably saw the elephant on both sides, with his trunk to the right and his tail to the left, and *vice versa*, and he got both a front and a back view of him. But obviously considerations of this kind only increase the difficulty we experience when we try to imagine what must really be happening in his brain, when the idea of the elephant, built up of these various sense impressions, takes possession of his mind and presently gives rise first to this and then to that other associated idea. How on the materialistic theory is the whole wonderful process going to be explained, when all that we know about the brain is that it consists of a vast number of cells with their inter-connecting fibres, and that nervous currents are continually coursing along these fibres from one set of cells to another?

3. Up to this point we have confined attention to the visual area at the back of the brain described by Dr Halliburton as the "cortical retina." But there can be no reasonable doubt that, just as the different cells composing this area are very numerous and are differently affected by

the different parts of the external scene, so it must be in a corresponding manner, though perhaps to a less extent, with the cells composing respectively the auditory, the gustatory, the olfactory and the tactile areas. But this leads to still further complications in the way in which on the materialistic theory we must suppose the brain-cells to be linked up with one another. Thus there are a great number of objects around us to the full conception of which several of our senses contribute. As a very familiar example I may refer to a piece of toast. It is known, of course, to be a piece of toast directly we see it, but a blind-folded person will be able to recognise it as such either by its taste, its smell, its peculiar roughness to the touch, or by the characteristic crackling sound which it emits when crushed. But if each of these sensations is sufficient of itself to enable anyone to identify it as toast, it is clear—on the theory which we are discussing—that to account for this, no end of the most complicated nervous connections must have been established in the brain between the *different* sensory areas. The same, of course, will hold true of multitudes of other objects. In each case we shall have to suppose that a similar set of highly complicated connections have been formed, and in such a manner as to ensure that, whatever may be the object under contemplation at the time, the nervous currents in the brain shall only pass between certain very definite collocations of cells in each of the said areas. And, should the attention presently be diverted to some other object, then all the nervous currents must be supposed at once to change their course and to pass between certain other equally definite collocations of cells—cells some of which are different from, while others are identical with, those which were excited only the moment before.

4. Among our various associations few perhaps are more important than those which have been formed between the various objects presented to our sight and the names by which we call them. But names, like words in general, are usually composed of two, three or more elementary sounds following one another in a certain fixed order. Of these elementary sounds we have nearly forty in the English

language, and it is to their different permutations and combinations that we owe our singularly rich vocabulary. But this being so, we are led to ask, By what conceivable sort of connections established in the brain are we to account for the fact, that the sight of any one of the innumerable objects around us immediately suggests, and in their proper order, just those elementary sounds which go to make up its name?

5. Still more perplexing perhaps is the fact that the vast majority of our names or nouns are "common nouns," and that each is accordingly associated with a number of objects all more or less differing from one another. Moreover, in their application some of these nouns are of extreme generality, such as "animal," "vegetable," "liquid," "gas," etc., while others are purely abstract, such as "cause," "character," "proposition," "infinitude." Again, we have adjectives to denote qualities, each of which is shared in perhaps by a large number of different objects, verbs to denote actions, each of which may be performed under a great variety of circumstances, and conjunctions and prepositions of a still more elusive character to denote certain relations. But this plunges us at once into fresh difficulties if, still convinced of the adequacy of the materialistic theory, we go on to speculate as to what may be the possible condition of the brain, and what may be the course taken by the nervous currents, when ideas in rapid succession and corresponding to these various parts of speech arise in the mind, and when, as in the case of a fluent public speaker, each idea calls up the right word.

As a good example, showing how the same elementary sounds when differently arranged may often stand for wholly different ideas, we may take the sounds represented by the letters A, K, T, S. We shall find that in our own language no less than nine distinct words can phonetically be formed out of them, thus :

AKTS acts	KATS cats	SKAT Skat ¹
ASKT asked	SAKT sacked	TAKS tax
KASt caſt	STAK ſtack	TASK task

¹ The name of a star in the constellation Aquarius.

But a list like the above only makes us once more put the question, By what possible arrangement of nerve-fibres, or rather perhaps by what rendering of any of them more permeable than the rest, are we to suppose that the associative links between these words and their meanings have been formed, when the only differences between the words lie in the order in which the same elementary sounds follow one another?

6. Again, in acquiring our own mother tongue, not only have we to establish connections between each idea and a certain definite series of sounds, but, in order to speak, we have to establish connections between each idea and an equally definite series of movements. And these movements are by no means simply produced. Each involves the contraction of a number of muscles—muscles of the chest and of the larynx and of the various parts of the mouth, such as the tongue, the palate and the lips.

7. Consider, too, the great difficulty which meets us if we try to explain, on the materialistic theory, how it is possible for any person to repeat accurately, say, the 798 lines of the first book of *Paradise Lost*, involving, as it does, the utterance on a rough computation of nearly 33,000 elementary sounds all in their right order. And yet the feat lies quite within the reach of an ordinary individual possessed of a fair memory, and must often be surpassed by our actors in the learning of their numerous parts.

8. Lastly, all these complications become still more complicated in the case of anyone who can converse in three or four different languages, and can do so without mixing up their vocabularies or committing any serious grammatical mistakes.

What, then, is the general conclusion to which the above considerations would seem to lead up? Surely this: that the brain, regarded simply as an object which can be probed and minutely examined by our senses, not only fails to explain, as we saw in the previous chapter, our conscious states in general, but fails to explain both how our innumerable memories are preserved intact, and how, when a highly complicated idea—throwing into activity perhaps a vast

multitude of cells—is about to suggest another, nervous currents at once begin to flow along certain definitely prescribed paths and to throw into activity perhaps another vast multitude. To try to account for all that goes on in the brain by what can be externally perceived in it, is like trying to account for the performance of one of Beethoven's sonatas by taking to pieces the instrument on which it is being played, the player himself and his important part in the business being utterly ignored.¹ It is to be noted, moreover, that if there are any two faculties of the human mind which, from the known structure and physiology of the brain, might antecedently be supposed to admit of a materialistic explanation, they are precisely memory and the association of ideas. Seeing that they do not admit of it, still less is it likely that any materialistic explanation will serve in the case of such higher faculties as, for instance, the reason and the will.² It is further to be noted that this failure to explain our mental faculties of whatever kind, by any knowledge of the brain and of its working which we may have acquired through our sense organs, is of a piece with all that we have learned in previous chapters as to the failure of every attempt to explain by similar means the facts of embryonic development. But what if both these failures proceed from the same fundamental cause, and if Life in all its various manifestations must necessarily remain inexplicable, so long as we will only accord reality to those things, or rather to just those aspects of things, of which our bodily and very limited senses can take cognisance?

There is one important point to which attention may now be drawn. If I was right in attributing the course of embryonic development to an indwelling, an invisible agent, viz. the psyche, and conceiving of it as possessed of a kind of memory, then the objection to which I alluded at the end of the previous chapter entirely loses its force, provided that

¹ "The body cannot store up images . . . it is a chimerical enterprise to seek to localise past or even present perceptions in the brain."—Bergson, *Matter and Memory*, p. 196.

² "There is infinitely more in a human consciousness than in the corresponding brain."—Bergson.

what I have been endeavouring to prove is correct. For if, contrary to what has generally been supposed, the *preservation of our ordinary* memories is independent of our brain-cells, then it can make no difference to their preservation whether the cells with which they are in some sort of mysterious connection are many or few. Similarly, therefore, it can make no difference to the preservation of those special memories which in the development of an embryo cause the reappearance of the various ancestral characters if, to begin with, they are somehow in mysterious connection with the germ-cell only.¹

The next matter to be discussed is one which I approach with a considerable amount of diffidence. "If," it may be said, "the preservation of our memories is not a function of the brain but of the mind, can we conceive of it in such a manner as to get rid of that confusion of superimposed images which on the materialistic theory seems so unavoidable?" I would suggest in the first place that what is preserved is not a number of isolated memories of this, that and of other matters, entering into our past experiences, but a continuous and ever-lengthening series of what I may term perhaps *Psychic Records, each representing a complete state of consciousness*.² Now into every such state there will enter, as a rule, a number of different elements—a number which will be greater or less according to the number of impressions which happen at the time to be streaming in from our various sense organs, and in most cases from certain purely mental sources as well. Let us denote these impressions by the letters *A, B, C, D, E, F*, etc. Not on all of them, however, will the attention be equally fixed. Thus *A* and *E* may be specially taken note of, *B* and *D* only slightly so, while *C* and *F* may be disregarded altogether. Hence for the resultant conscious state we may use as a symbol the

¹ "That experience can be enregistered in organisms with the simplest of nervous systems or with none is certain."—J. A. Thomson, *The System of Animate Nature*, p. 191.

² "It is convenient sometimes to speak of 'states of consciousness' as though each were a distinct and separate entity. In reality, however, our so-called 'states of consciousness' flow on into one another and form a continuous stream."—See Bergson, *Creative Evolution*, p. 2; also William James, *Textbook of Psychology*, p. 151.

letters A, b, d, E ; and among these we will suppose that A stands for the sight of some particular object, and E for the simultaneously heard sound of its name. Now so long as this conscious state continues practically unchanged, we must assume that certain currents are flowing along paths in the brain corresponding to A, b, d, E —currents, however, which, when this conscious state is succeeded by another, are diverted and constrained to take a quite different course. But although the former state will itself have passed away, I conceive of it as having left behind it *in the subconscious region of the mind*, that is, in the psyche, a faithful record of itself, which I will denote by A', b', d', E' , and which will be ready now at any future time to react upon the brain, directing the currents into the same paths again and thus reproducing, though in a less vivid form, the original experience.

Further, that there may be no kind of confusion, these records must be conceived of as stored away *separately* in the psyche, much after the same manner in which, if I may use a very material illustration, a number of photographs or engravings are often kept piled up on the top of one another¹ in a portfolio. Also, in many cases, as in the repetition of a well-known piece of poetry, they must be thought of as acting on the brain in precisely the same order as that in which they were originally produced.

Such a theory involves, of course, the idea that the brain is the recipient of two totally distinct sets of impressions, viz. those which are conveyed to it by the sensory nerves and which bring in their reports as to what is happening in the external world, and those which in some not fully understood way are the result of the activity of the psychic records—an activity which restores to consciousness, though in an ideal form, past scenes and events. In so doing we need not suppose, however, that there is any infraction of the great principle of the Conservation of Energy, but simply that the total amount of current which previously perhaps was flowing diffusedly, and therefore feebly, through a large number of channels, is now forced to flow in greatly

¹ Here again in reality of course they are continuous.

increased volume through special channels only, thereby evoking first this and then that other conscious state.¹ That even in profound slumber there should be currents in the cerebral hemispheres of this diffuse and feeble kind seems far from improbable, when we know that from another part of the brain, the medulla, currents somewhat similar are continually flowing outwards, which help to control the action of the heart and exert a certain tonic influence on the smaller arteries. In dreams, which occur, as a rule, immediately before waking, we must suppose that our psychic records are just beginning to renew their activity, suggesting to us all sorts of heterogeneous ideas which we are unable to control, because the critical faculty and the will are still in abeyance. When we are fully awake, however, and the will has resumed its proper function, though it cannot summon ideas at its beck and call, it can exercise its authority over them as soon as they arise, retaining some in the field of consciousness and dismissing others. Of course, this means again a strengthening of the nervous currents flowing along certain channels, and a corresponding weakening of them in others—an effect which may well be caused by some action of an inhibitory kind which increases the resistance at certain of the synapses.² On this theory, then, the course pursued by the currents, and by the accompanying conscious states, is determined in part by impressions reaching the brain from without *viâ* the organs of sense and the incarrying nerves, in part by impressions produced on it from within by the psychic records, and in part by the action of the will.

If, however, our conscious states are in this way largely influenced by our psychic records, it is surely not unreasonable to suppose that the relation between them may be a reciprocal one, and that our already accumulated psychic records may often be influenced in a peculiar way by our conscious states. It may well be, for instance, that every conscious state tends to rouse into activity the records of

¹ Reference may here be made to the illustration of the pointsman, Chapter XI.

² See Chapter XI and fig. 14.

any previous states which at all resemble it, and that these records in their turn are ready then to react upon the brain. What happens may be compared perhaps to the way in which a tuning-fork when vibrating will cause another to do the same, if it is of the same pitch. Now this would account for the so-called *Law of Similarity*, according to which any idea always tends to call up others which are like it. It would also account for the *Law of Contiguity*. For suppose, as in the illustration already given, that a psychic record has been formed of a conscious state, which may be represented by A, b, d, E , and in which A stands for the sight of a certain object and E for the simultaneously heard sound of its name, then if at any future time a conscious state should occur represented, say, by A, d, l, m , the A and d in it might tend to recall the conscious state A, b, d, E , and therefore the E in it which is the sound of its name. Conversely, a conscious state E, b, k, q might, because of the E and b in it, tend to recall A, b, d, E , and therefore the A in it; or, in other words, the sound of the name of the object might recall the object itself. Thus the two generally acknowledged *Laws of Association* would to a certain extent be explained.

At the beginning of this chapter I referred to some of the reasons which have been given in support of the usually accepted theory that our memories, or rather certain physical impressions which our past experiences are supposed to have made, are somehow lodged in our brain-cells. If a blow on the head or an anæsthetic temporarily obliterates our memories, if old age permanently impairs them, and if serious disease occurring in the sensory areas of the cortex will sometimes apparently quite destroy them, then most that has been advanced in this chapter would seem at first glance to fall to the ground. And yet why should it, if only we keep clear in our minds the important distinction between the function by which our ideas are stored up and preserved and the function by which they are afterwards revived? So far as the latter is concerned we may well believe that the brain, or some other organ answering to it, may be necessary; but it does not follow that this need

be the case with the former. A musician who could play by heart one of Bach's fugues would be quite unable to do so if he were seated at an organ in which half the notes were out of tune, broken or entirely wanting. The fugue, however, would not thereby have ceased to exist. Given another and more perfect instrument and it could once more be reproduced. So I conceive it to be with our memories. They are not necessarily destroyed because the brain, the merely material mechanism, happens to get out of gear or to fall to pieces at death. For, as we shall see in our last chapter, the belief in human survival rests upon much firmer foundations than is sometimes supposed, and if so, what is to hinder some new and appropriate organ being provided by which the said memories will be revived?

In conclusion, it may seem perhaps to the reader that the various considerations put forward in this chapter, whatever weight may be accorded to them, do not carry us very far towards the end which was proposed. In other words, if a kind of memory is to be invoked to explain the orderly sequence of events in embryonic development, such a memory would seem to stand at far too great a remove from memory as ordinarily understood. There is obviously a great gap between the two, and the question therefore is, How, if at all, can this gap be bridged? To this subject, therefore, I intend to return in the following chapter.

Additional Note.—It often happens that on meeting some one whom we know perfectly well we are quite unable at first to recall his name, while at the same time we have the feeling that it is floating about somewhere in the dim recesses of the mind. This may be due to the fact that the activity of the "psychic record," in which the sound of the name is preserved, has not yet been fully aroused; and that consequently the brain currents corresponding to the name are not yet flowing strongly enough to bring about revival, although in sufficient volume perhaps to account for the peculiar mental state in question. If presently, however, from any cause their volume should be increased, the name will suddenly flash into consciousness.

CHAPTER XXIII

MEMORY AND INSTINCT

HITHERTO I have made no reference to the important fact that our memories fall into two quite distinct classes. As M. Henri Bergson has pointed out in his treatise on *Matter and Memory*, they are either of the ideational or of the motor variety. As an example of the former, suppose I happen to be looking at a sundial. This may give rise in me to several alternative trains of thought. Thus it may make me think of the sun, and next perhaps of the spots on its disc and of the various theories which have been put forward to account for them. Or, from thinking of the sun, I may pass on to the moon and to its mountains, and then to certain mountains on the earth, such as Snowdon and Mont Blanc, which will probably revive in me all sorts of pleasant memories of North Wales and Switzerland. Or the sundial may set me off on an altogether different track by suggesting some of the other means by which time is measured, *e.g.* by a clock, by an hour-glass or by the burning of a certain length of candle. If a clock is suggested, I shall perhaps find myself thinking the next moment of the great clock at Westminster and of the Houses of Parliament, and then of the last election and of how the member for my own division was returned by a thumping majority ; and so on quite indefinitely. The point, of course, to be noted here is that, unless the will comes in to steady and give direction, we may be conducted by our trains of thought almost anywhere. The number of alternative paths becomes practically infinite.

It is quite otherwise, however, with our motor memories, of which the illustration I gave in the preceding chapter is perhaps as good as any. I refer to the repetition without

a mistake of a number of lines of poetry. Here the movements made, in which chest and larynx, tongue, palate and lips all play their part, follow one another in a certain prescribed order—an order from which there will be no departure, provided that the lines in question have been thoroughly got by heart. The same remark applies to the singing of familiar tunes and to the way in which a pianist will sometimes rattle off an elaborate piece of music without paying the least attention to the score. It applies also to those shorter series of concatenated movements involved in walking, running, swimming, skating, cycling, etc.

Another characteristic of these motor memories is that, the more firmly they have become established in us, the less needful is it, as a rule, that they should be accompanied by consciousness. In most cases, indeed, the sequence of movements will be gone through all the better, all the more infallibly, if the attention is not directed to them. It is quite possible even to repeat correctly forty or fifty well-known lines and at the same time to be occupying the mind with something entirely different, as, for instance, adding up a column of figures—a feat which with a little practice soon becomes comparatively easy. Whenever this happens, the psychic records must be conceived of as acting on that particular part of the brain which forms the great motor area in front of the fissure of Rolando, thereby causing the various movements to follow one another in their proper order, while in another part of the brain, for the time being more immediately connected with consciousness, the work of addition is being done.

It is true that the late Professor William James sought to give these motor sequences a purely mechanistic explanation.¹ Thus if *A*, *B*, *C*, *D*, etc., represent a succession of movements of the kind which we are considering, then according to him *A* does not *directly* give rise to *B* but to *a*, a symbol which may be taken as standing for certain effects produced in the brain by currents returning from the muscles, tendons and joints which have been concerned in the movement

¹ William James, *Principles of Psychology*, vol. i, p. 116; see also vol. ii, pp. 582-592.

just ended. Now it is these effects which he would have us regard as forming the immediate cause of *B*. In the same way *B* gives rise to *C*, not directly, but through the mediation of certain other effects which may be represented by *b*; and so on with all the other members of the series. The subjoined diagram, taken from his book,¹ but modified, is designed to illustrate this :

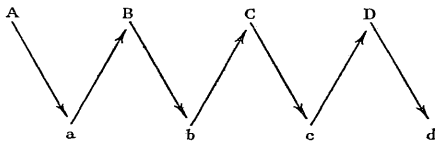


FIG. 50.

Now such an explanation might conceivably hold good in those cases in which the members of the series are comparatively few in number, but what are we to say, when it is a case like that of repeating without a mistake the whole of the first book of *Paradise Lost*, in which, as we have seen, no fewer than 33,000 elementary sounds have to be reproduced, and all in their right consecutive order? To me at least it seems quite incredible that the obscure impressions—and they must be exceedingly obscure—produced by the currents coming back after each combination of movements from larynx, lips, tongue, etc., should be sufficient to ensure the extraordinary accuracy with which the entire book can be repeated. And it seems all the more incredible, when we reflect that out of this succession of 33,000 elementary sounds there are only about forty which are really different, and that hence each of them during the recitation has not only to occur on the average 825 times, but to occur each time in its right relation to the other elementary sounds immediately preceding and following it.² Now I submit that it is extremely difficult, if not quite

¹ *Principles of Psychology*, vol. i, p. 116.

² I find, as illustrating this point, that the word "eternal" occurs in the first book of *Paradise Lost* seven times over, viz. in lines 25, 70, 121, 154, 155, 318 and 610, but that it is followed in each case by a different word—by "providence," "justice," "war," "being," "punishment," "spirits"

impossible, to account for this either on Professor James's theory or on any other theory of a like mechanistic character. The whole thing is surely far better and more easily explained on the supposition that a complete series of psychic records has been formed of the lines in question, and that it is these psychic records which, by their successive action on the motor area of the brain, cause the correct and orderly repetition of the lines. Such action may be compared, though the comparison I admit is an imperfect one, to that of a pianola on the piano to which it is attached; or again, to that of the jacquard which, by its control of the movements of a loom, causes it in the weaving, say, of a piece of brocade, to produce so beautiful and elaborate a pattern.

Another characteristic of these series of motor memories is the impossibility of reversing them, of repeating, for example, a number of well-known verses backwards, or of singing backwards a well-known tune. Of course, if we choose to do so, we can go to the trouble of learning backwards both the verses and the tune, but in that case it will mean the formation, and the getting off by heart, of practically altogether new sequences.

From what has now been said it would appear that if that extraordinary series of progressive changes through which an embryo passes on its way to maturity is to be attributed to some sort of memory lodged in its psyche, then such a memory does in a most remarkable manner resemble one of the motor memories just referred to. Both are marked by the definiteness, the length and the complexity of their sequences, by their inevitableness and irreversibility, and by their apparent independence of any conscious accompaniment. I venture, therefore, to say that the gap alluded to at the end of the previous chapter has to a very large extent been filled up.

There are still, however, as between our ordinary motor memories and those which I would attribute to the developing embryo, certain outstanding and somewhat important

and "splendours." And yet, if the book has been thoroughly committed to memory, the word "eternal" each time it occurs will call up just the right word which should follow it, and not any of the other six.

differences. The motor memories are acquired during the lifetime of the individual and are the result of a process of learning, whereas the others are inherited, they are somehow passed on through the germ-cell, or rather through that which constitutes its inner, its unperceived reality. Again, in the first case we have the production of a series of movements which are brought about by means of nerves and muscles, whereas in the second case not only are the movements for the most part of quite another kind—as in the differentiation of the various sorts of tissue and in the infoldings and outfoldings of the three primitive layers, etc.¹—but they result in the construction of a body complete in all its parts, nerves and muscles included. What we have to do, then, in order still further to strengthen our argument, is to try and discover cases occupying a somewhat intermediate position between the two just referred to. With this end in view let us turn attention to the instincts, or rather to those automatically performed series of *external* actions which we generally describe as instinctive, because they are innate, not needing, therefore, to be acquired afresh by each new individual.

Now among the many examples of instinctive action which the animal world displays, perhaps one of the best for our purpose is that afforded by the *Araneida*, or true Spiders, and especially by that section of them which weave circular snares. Not all of these snares are alike; they differ from one another in several particulars according to the species. Some, as in the case of the garden spider, *Epeira diademata*, are stretched out vertically, others horizontally; some form complete circles, others only partial ones; to some there is added what is known as the labyrinth, while in others the labyrinth is only very imperfectly developed or is entirely wanting; and so on with a number of other slight differences.² Taking the circular snare of the garden spider as a type, it is easy to make out in it the following parts. First, there is the small

¹ See Chapters XIV and XV.

² For fuller particulars consult H. C. McCook on *American Spiders and their Spinning Work*.

central area or hub. In this the threads are arranged very irregularly, the meshes of the network being of various shapes, though chiefly polygonal. Some spiders, however, like *Acrosoma rugosa*, omit this network altogether, leaving the centre hollow, while others, like *Argiope cophinaria*, cover the hub over with a little mat of closely interwoven silky filaments. Next, extending from the margin of the hub in all directions, there are a number of radiating threads set at more or less equal distances apart and resembling the spokes of a wheel. On these are stretched in ladder-like fashion a series of cross-pieces, which on closer inspection turn out to be parts of a couple of spirals. The inner one immediately surrounding the hub is known as the *notched spiral*, because at each point where it crosses a spoke it slightly shifts its position. The outer and much larger spiral does not exhibit this peculiarity, and is further distinguished by the circumstance that its threads are covered over with a sticky substance which, immediately after it has been applied by the spider, gathers itself up into a multitude of minute droplets. It is hence known as the *viscid spiral*, and is for the purpose, of course, of entangling insects. Under the microscope these droplets present a most beautiful appearance, looking very much like a number of pearls strung together on a lady's necklace. Between the notched and the viscid spiral there is generally a gap, the so-called *vacant zone*, in which the cross-pieces uniting adjacent spokes are absent. Such an arrangement enables the spider to pass with ease from one side of the snare to the other. *Acrosoma rugosa* accomplishes this, however, by passing through the space left empty in the centre, and therefore in her case the vacant zone is not needed, and consequently does not exist.

I have now mentioned all the parts forming the orb or circular snare proper, but outside of it and supporting it there is always the carefully constructed framework by which it is attached to branches of trees, fences, gateposts, or to other conveniently situated solid objects. This framework is composed of a number of irregularly disposed threads, which are so arranged as to give strength and stability to

the entire structure. Some of these threads, particularly the outer ones, are known as the foundation lines. To render them extra strong they are often quadruple, and are the first which the spider lays down. In this, and in the construction of the framework as a whole, one is bound to recognise that something more than mere instinct comes into play, seeing that the number, the direction and the joinings of the various threads have to be adapted to the size and the peculiar shape of the space in which the web will presently be woven. Hence although instinct, to begin with, may prompt the spider to set about her task and may determine its general character, in this particular portion of it at least she is guided by what looks very much like intelligence.

Let us suppose now that the framework has already been completed. The next thing which the spider does is to drop a vertical thread from one of the upper foundation lines, so as to let it pass through the point which will eventually become the centre of the snare. This thread she fastens to some fixed object down below, or else, as is more often the case, to a second foundation line. Climbing up again to the central point she attaches to it another thread, which she carries up to the top, continually spinning out more and more of it as she goes. She now pulls it tight, and, by fixing its further end to some point on the outer framework, puts in her first spoke. By repetition of a precisely similar set of movements she next puts in one by one all the remaining spokes, returning each time to the centre to attach the new thread and then carrying it out to the circumference as before. Although the order in which these spokes are put in is not an invariable one, a certain principle seems to be followed which is worth noticing. If, for example, there are to be twelve spokes in the snare, answering roughly in their position to lines drawn from the centre of a dial to the numbers indicating the hours, then the spider will not insert them in the order 1, 2, 3, 4, etc., but after inserting, say, 1 and 2, she will cross over to the other side and insert 7 and 8, so as to counteract the pull of the first two. Next perhaps she will

insert 4, and then cross over and insert 10 and 11, and so on till the full number is complete. So here once more we seem to have instinct guided by intelligence.

Meanwhile, that is during these repeated visits paid to the centre, the hub has been gradually formed, and now the spider proceeds to put in the notched spiral, working from the hub outwards. Presumably the purpose of this spiral is to tighten the spokes and so brace up the entire structure. Next, having passed over the space which will become the vacant zone, the spider spins what is known as the *temporary spiral*—the spiral which is presently to serve as a kind of scaffolding for the construction of the far more important viscid spiral. The turns of this temporary spiral are somewhat few and far between, and, like those of the notched spiral, are put in from the centre outwards. It is otherwise with the turns of the viscid spiral, which are put in next, for now the spider works from the circumference inwards, using at the same time a different kind of silk, a more elastic one, and smearing it over with the sticky substance which, as already said, gathers itself up into minute droplets. While doing so she removes bit by bit the temporary spiral, though *Nephila plumipes*, one of the largest of the American species, allows it to remain.

The next thing which the spider does, if not done already, is to construct the little nest which is to serve both as a safe retreat and as a place in which to lay her eggs. It is mostly situated at some little distance from the snare, but is always connected with the latter by means of a sort of gangway, consisting usually of a couple of trap-lines leading down slantingly to the hub. This enables the creature at first note of warning to rush out quickly from her lair and pounce upon her prey. The nest is, as a rule, hidden away in a crevice in the wall or in some other retired nook, or else, as in many species, it is surrounded by a highly complicated mass of threads running in all directions—the so-called labyrinth or maze, which effectually prevents the intrusion of unbidden guests like wasps and flies.

Reverting to the snare, I may add that in several species the cross-threads are omitted over one or two of the adjacent

sectors. Whenever this is the case, as in *Epeira triaranea*, the spirals are of course incomplete, and, in beginning each fresh round, the spider is compelled to turn right about and continue her task, travelling in the opposite direction.

Another interesting snare is that spun by *Epeira basilica*. It is a wheel-shaped structure like the one already described, but it is spread out horizontally. The spider, however, is not content to leave it so, but proceeds to convert it into a kind of umbrella-shaped dome by pinning it down along its circumference with a number of special threads, and, with other threads attached to its more central portions, drawing it up into the shape required—truly a most remarkable achievement.

I have dwelt thus at length on these extraordinary performances of the spider, because we seem to have found in them just the kind of thing of which we were in search. For, on the one hand, the movements involved not only constitute a definitely ordered series and are performed externally to the body, but they are effected by means of nervous currents and muscular contractions, in all these respects closely resembling those definitely ordered series of movements which in ourselves are the result of acquired memories. On the other hand, the movements are *not* acquired, but *inherited*, in this respect resembling the definitely ordered series of changes—each of them at bottom resolvable into movements—which mark the course of embryonic development. That they are certainly inherited is shown by the fact that if a spider soon after it is hatched is removed from its parents and from all others of its kind, it will, when it grows up, go through with almost clocklike precision the various operations necessary for spinning that particular sort of web which is characteristic of its species. Putting, then, these facts together, they tend very considerably to confirm us in the belief that the development of the individual from the germ-cell onwards is determined in a manner very closely analogous to what happens in the case of our motor memories.

It may possibly be objected that the spinning operations of the spider are not after all entirely instinctive, but that

intelligence comes in from time to time to play a part in them as well. Thus, as we have seen, there is the adaptation of the outer framework of the snare to the size and peculiar shape of the space in which it is to be inserted; there is the order, likewise dependent upon circumstances, in which the spokes are laid down; and there is often, if the web should afterwards be broken, a certain amount of repair to be done, which will vary according to the extent and whereabouts of the injury. But to this sort of objection the obvious answer is, that the same is also true of our motor memories, and of the series of movements to which they give rise. For although they work as a rule automatically, that does not prevent us every now and again from consciously intervening and imparting to them a new direction. For instance, a man who goes daily to his place of business need not do more each time than give the start to that rhythmical series of muscular contractions which of their own accord, so to speak, will take him to his destination. If, however, on his way he should be handed an unexpected telegram, he will as likely as not alter his course and proceed at once to the telegraph office to send off a reply. In other words, by the receipt of the telegram his intelligence has once more been brought to bear upon his movements, and a change in them has been the result.

Again, as to any subsequent mendings of the web, are they not closely analogous to what takes place when a lost limb or other organ is regenerated, or when after some such violent treatment, as was described on pages 255, 309, an embryo nevertheless succeeds in righting itself, as if determined in spite of all obstacles to reach its appointed goal?

Another important point is this, viz. the very close relation in which these spinning operations of the spider stand to its previous development. Obviously it would be unable to spin its web at all if it had not already been furnished with the necessary organs for doing so. These organs consist of three pairs of *spinnerets*, six in all, arranged in a little clump on the under surface of its abdomen. They are somewhat finger-like in shape, and are covered over near

their tips with a great number of minute projecting tubes known as *spools*, together with a few much larger ones known as *spigots*. Each of these with certain exceptions emits silk, and is in communication with a separate gland in which the silk is secreted. The silk, too, is of five different kinds to suit the requirements of the different portions of the web. Three of the spigots, however, instead of emitting silk, emit the peculiar sticky substance wanted for the viscid spiral.

Now, wonderful as may appear the provision of these special organs in the case of the spider, it is not really more wonderful than the provision in animals generally of those numerous other organs, the functions of which are performed internally. In fact, between these two kinds of provision there is no essential difference. If hidden away in the human germ-cell there is that, for example, which causes the digestive organs to arise and afterwards bids them digest, similarly hidden away in the germ-cell of the spider there is that which causes the spinning organs to arise and afterwards bids the creature put them to their intended use. Is it not by a kind of instinct, one might almost say, that the stomach digests, the lungs breathe and the heart beats? As M. Joussain remarks in his *Outlines of a Philosophy of Nature*: "Instinct is a prolongation of the organising work: the effort by which the chick breaks its shell, frees itself from the debris and begins to walk, is a continuation of the development by which its organs have been built up in the egg."

As the result, then, of our considerations in this and in the preceding chapter, we may classify the different kinds of memory as follows:—

A. Memories ideational, acquired, accompanied by consciousness. (Example: Trains of ideas like those mentioned above.)

B. Memories motor, acquired, which by means of nerves and muscles set going certain series of external movements. They may or they may not be accompanied by consciousness. (Example: Playing through mechanically a well-known piece of music.)

C. Memories motor, inherited, which cause the development of peculiarly specialised external organs, and which afterwards, by making use of these organs, cause a series of external movements to be automatically performed. They are probably accompanied by a certain amount of consciousness. (Example: Actions gone through by a spider in spinning its web, following upon the previous development of the spools and spigots, etc.)

D. Memories motor, inherited, which cause the development of the body as a whole, especially of its internal organs, and which afterwards constrain them to perform their several internal functions—functions which in the last analysis consist of movements. They are in most cases entirely unaccompanied by consciousness. (Example: The circulation of the blood following upon the previous development of the heart, arteries, veins, etc.)

Thus these four different classes of memories would appear from the above to form a consecutive series, in which classes *A* and *D*, though they seem at first sight to possess little in common, are nevertheless shown to be related to one another by means of the intermediate links supplied by classes *B* and *C*.

The final conclusion, then, to which we have gradually been led up, and for which in this chapter we have been seeking further confirmation, is that the psyche, as it exists in the germ-cell, must be possessed of a faculty very closely akin to what we ordinarily understand by memory, and that, as development proceeds, it is this faculty which causes all the successive stages to follow one another in their proper order and to be a repetition of what previously occurred in the case of the parents. I conceive, therefore, of the germ-cell—which in the human species appears to the eye as merely a minute speck of protoplasm $\frac{1}{250}$ th of an inch in diameter—as potentially charged from the very first with all that marvellous complexity of structure, function and varied activity, which will be afterwards fully displayed when the development is complete. But when I say “the germ-cell is charged” with it, I am referring, of course, to that deep underlying reality of which the germ-cell, as

it appears to our senses, is only the material embodiment, the outer husk or shell.

As to the conscious self, may we not regard it as a highly evolved portion, so to speak, of the psyche, different from it and yet in a sense continuous with it? Apparently it is found only in animals, and in them in very various degrees of development, according to their position in the scale of life reaching up from the lowest forms to Man. Concurrently, of course, with the development of the conscious self there has been in the past, and there is still, in the case of every fresh individual to-day, a development of the brain and of the nervous system. With these the conscious self stands in very intimate relation, just as the psyche stands in very intimate relation with the body as a whole. Or possibly it would be more philosophical to say that the two developments just mentioned are really one and the same, that which we call the body being the psyche itself as it presents itself at any given moment to our senses, and that which we call the brain—or perhaps I should say “the cortex of the brain”—being the similar presentment of the conscious self. Be that as it may, however, if it is the function of the psyche charged with all its ancestral memories gradually to construct the body, so as to adjust it to all the general conditions of existence, it is among other things the function of the conscious self rapidly to adjust the body by means of the brain, the nervous system and the voluntary muscles, to all those special, very varied and often exceedingly sudden changes which from time to time occur in the environment. And, further, it is in order to deal with these changes—though there may be higher ulterior reasons as well—that we have apparently been provided with memory of the higher ideational kind, together with all the rest of our intellectual faculties, such as the power of making decisions and of carrying our decisions into effect.

In conclusion, it may perhaps be of some service if I give here a short résumé of the general line of argument, as contained in this and in several of the preceding chapters. And first, in Chapters XIV, XV and XVI I tried to set forth some of the principal facts in connection with that

most astounding of all Nature's processes, viz. that in which the comparatively simple germ-cell is slowly transformed into the highly differentiated adult organism. But the human mind can never rest satisfied with the mere enumeration of facts ; it invariably seeks for an explanation of them, and hence Chapters XVII, XVIII and XIX were devoted to a description of some of the principal theories which have been put forward on the subject in the past. This led to the discussion of Darwin's theory of Pangenesis and of Weismann's theory of the Ids, together with some account of those remarkable laws of heredity first discovered by Mendel, and of the more recent Factorial Hypothesis associated especially with the name of T. H. Morgan. But although a number of the most interesting facts had been brought to light in the endeavour to establish these theories, not one of the latter—so we saw in Chapter XX—provided us with a really adequate explanation. We were left almost as much in the dark as we were before. Yet why should the search have proved so unavailing ? That was the question which we asked at the beginning of Chapter XXI, and the answer occurred to us, that it might possibly be due to our neglect of certain important considerations.

Now few things were more certain than that all our knowledge of the external world, and of embryological processes in particular, was derived from one set of sources only, viz. our bodily senses. But what real warrant had we for supposing that these senses of ours—so few in number and so limited in range, and which had primarily been evolved for the purpose of enabling us to obtain just food and shelter—were competent to inform us of the innermost reality of things, or, if not competent at the present time, would eventually become so, when we might be provided perhaps with more powerful instruments and with more refined methods of research ? If, however, we had no such warrant, then our failure to perceive the hidden links which bind together in a causal chain the successive events in the development of an individual organism, might be due to our not looking in the right direction ; and it

might well be that, could we only penetrate beneath the outward appearances of these events, the mystery surrounding the whole subject might in part at least be dispelled. The question therefore became, Was it possible to penetrate beneath these appearances? And in our endeavour to answer that question we seemed to find a clue close at hand in the human brain. For here, in the human brain, we undoubtedly come across something which is far more than what appears, or can ever be made to appear, to our senses—a something which is conscious, which can think and feel and desire, can form purposes and devise means for accomplishing them. But how has the human brain—or rather, we will say, the cells composing it—come by such remarkable psychic powers? The cells in question have all been derived by repeated subdivisions from the original germ-cell, and therefore, unless we are prepared to set the Law of Continuity on one side, we seem compelled to assign a certain psychic character to the germ-cell itself—a conclusion which is borne out by the fact that mental, as well as physical, peculiarities are frequently inherited.

The next thing was to show why this psychic character must be extended from the germ-cell to at least two other important groups of cells in the body, and thence by an easy transition to the body as a whole. Moreover, as there were several indications all tending to show that any poly-psychic theory was out of the question, we arrived at the conception of a single psyche, which not only stood in present relation to the body, controlling all its various activities, but had been the determining cause of its past development as well. And we were strengthened in our belief on this latter point because, whatever might be the exact nature of the psyche, it resembled in its working the fully conscious mind in at least the five following particulars: (1) It could construct; (2) it could construct so as to realise a number of different purposes; (3) it could co-ordinate these purposes and, as was explained in Chapter XII, make them subserve still higher and more comprehensive ones; (4) it could overcome, or at least circumvent,

many of the obstacles lying in its path ; and (5) it appeared in these matters to be possessed of a kind of memory which enabled it to repeat, as development went on, most, if not all, of the successive ancestral stages.

But at this point the objection naturally arose, How could anything in the nature of memory be passed along through the solitary germ-cell, if memory was to be regarded as merely a function of the brain, or rather of a vast assemblage of brain-cells, in which individual memories, or at all events their physical impressions, were stored away ? We were thus led in Chapter XXII to combat this widely prevalent notion, and to maintain instead that our memories exist independently of our brain-cells, and indeed of all cells whatsoever, and therefore independently of the circumstance whether the body at any given stage in its development consists of one, of a few, or of a great number of cells. At the same time there seemed to be a very wide gap between memory in the ordinary sense of that term and the kind of memory which we were attributing to the developing organism. This gap, however, we have tried to bridge over in the present chapter by showing how the kind of memory, which we have supposed to control embryonic development, bears a striking resemblance in many ways to our so-called motor memories, and how we may find yet another connecting link in those remarkable instinctive memories of which the orb-weaving spiders furnish us with so excellent an illustration.

By way of re-emphasising what has just been said I may add the few following remarks.

On the usually received theory, the memories which we have acquired during perhaps a long lifetime—or rather, as is supposed, their physical impressions—are preserved in the multitudinous cells forming the cortex of the brain. But why should a *multitude* of cells be considered necessary, if a single cell, viz. the minute germ-cell, is sufficient, as we have seen, for the preservation of those infinitely complex and far more numerous memories which somehow order and control the course of individual development ? And that a single cell should be equal to so prodigious a task

does certainly seem to suggest the idea that it is not the cell in itself—as perceived, that is, by our very limited bodily senses—which accounts for the whole wonderful process, but rather that unseen underlying reality which I have postulated and termed its psyche. To the germ-cell, indeed, we might almost apply those lines of Wordsworth addressed to the newly born infant :

Thou, whose exterior semblance doth belie
Thy soul's immensity.

As to the cause or causes which in the case of beings like ourselves have been at work, enabling the germ-cell to accumulate so vast a stock of memories—it is a question which we can only properly discuss after we have considered the modern doctrine of Evolution. So the next few chapters will be devoted to that subject. Meanwhile, it is important to observe that the general conclusion which we have reached, as to the manner in which our memories are preserved, strikes at the root of any theory of the Universe which would explain it only in terms of matter and of its various physical and chemical forces. Whether the same conclusion can be drawn from our present-day knowledge of the great Inorganic Realm is quite another question, and one on which I may have something to say later on (Chapter XXIX).

Note.—The theory which I have above advocated, in order to account for the development of the individual, is essentially the same as that put forward in Germany by Ewald Hering, as also in our own country by Samuel Butler (see his work entitled *Unconscious Memory*). What I have sought to do is to modify it somewhat, and to render it more precise by bringing in a number of additional considerations. See, too, in this connection Dendy's *Outlines of Evolutionary Biology*, pp. 186–193.

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CHAPTER XXIV

EVOLUTION AS A FACT

HAVING finished all that at present need be said about Life as displayed by individual organisms, I pass on to those broader aspects of it arising out of the circumstance that, according to the doctrine of Evolution, all the innumerable species of animals and plants, which have at any time inhabited the earth, are genealogically related to one another, and together constitute, therefore, one vast all-embracing system. Before doing so, however, it seems desirable that some brief account should be given of the evidences on which the said doctrine rests, and especially as hitherto I have only casually alluded to them. I propose, therefore, to devote the present chapter to their consideration, so that we may be the better able to proceed afterwards to that extremely important, but entirely distinct question, as to the cause or causes which have brought Evolution about.

Now, as already stated,¹ it was formerly the well-nigh universal belief that every species had had a separate origin, all the individuals belonging to it having been descended from a single pair, which owed its existence either to a special Divine act, or to some cause or causes quite unknown. Connected with this belief was the assumption that every species was in its essence unchangeable, and that, whatever slight differences might appear from time to time among the individuals composing it, thus giving rise to new varieties, these varieties could never overstep certain well-defined limits. The Evolutionary doctrine, on the other hand, boldly challenges this position, and maintains that, as generation succeeded generation, these differences continued to increase, and often to such an extent as to produce

¹ See Chapter II, paragraph 10.

at last an entirely new species. Further, all the larger groups into which animals and plants have been divided, such as genera, orders, classes, etc., are to be conceived of as having arisen in a similar manner, so that Life, as it has existed in the past and as it is still existing on our planet to-day, is to be regarded as essentially one, in spite of all the infinitely diverse forms into which it has gradually branched out.

What, then, are the evidences on which this theory, this great modern generalisation, is based? They are several in number, and depend on considerations relating to (1) the Classification of Plants and Animals, (2) their Anatomical Structure, (3) their Succession in Time, (4) their Geographical Distribution, (5) their Embryological Development, and (6) certain Changes taking place in them which have been observed in Recent Times. Let us pass in review each of these in turn.

I. *Classification*.—The argument here depends upon the circumstance that, when plants and animals are arranged according to their various degrees of resemblance, they fall into a number of groups and subgroups and still smaller divisions, strongly suggestive of the idea that they are all somehow related to one another by the ties of common descent. In other words, these groups and subgroups and still smaller divisions seem naturally to assume the form of a very much branched genealogical tree.¹ To appreciate, however, the real force of this, it would be necessary to go into an immense amount of detail, such as lies altogether outside the scope of the present work. And even if this were done, the argument would scarcely seem conclusive apart from the following much more cogent lines of proof.

II. *Anatomical Structure*.—In outward form and appearance there would not seem to be much in common between a human being and a horse, and yet, when as in the Natural History Museum at South Kensington we see their skeletons set side by side, few things are more striking than the manner in which, in spite of very marked differences, they correspond with one another almost bone for bone. Now how are we to account for this correspondence? The explana-

¹ See fig. 1, p. 23.

tion given is, that it is due to the fact that human beings and horses are in some very distant way genetically related to one another—in other words, that the reason why their skeletons reveal the same general plan is that they have inherited it from some very remote common ancestor.

Suppose now we restrict attention to the bones of the forelimb. We know that in ourselves these consist of (*a*) the *Humerus*, or single long bone, reaching from the shoulder to the elbow, (*b*) the *Ulna* and the *Radius*, reaching from the elbow to the wrist, (*c*) eight wrist bones, (*d*) five bones situated in the palm of the hand, and (*e*) five sets of digital bones, two bones in the thumb and three in each of the four fingers. Now when we compare these with the same bones in the forelimbs of other mammals, as, for example, the lion, the bat and the dolphin, we are once more struck by their extraordinary correspondence. Though some of them are longer and others are shorter than in ourselves, and their number is not absolutely fixed, yet their general arrangement is practically the same in all these animals. And, what is still more remarkable, this is so in spite of the fact that in ourselves the forelimb has been modified in such a manner as to enable us to grasp and manipulate things, in the bat it has been transformed into a wing for flying, and in the dolphin into a paddle for swimming, whereas in the majority of quadrupeds it still retains its original function of walking. But by the very use of such terms as “modified” and “transformed,” which in this connection so readily rise to our lips, the doctrine of common descent would seem to be implied.

Or take the elephant. To most people it must be evident that its highly characteristic trunk is really a much transformed, a greatly elongated, nose, which now performs a prehensile as well as a respiratory function. Moreover, its incisor teeth, of which we possess eight and many animals twelve, have been reduced to two only—both of them in the upper jaw—and these have been converted into enormous tusks, no longer acting as teeth, but as formidable weapons of offence.

Still more conclusive is the evidence derived from *Vestigial*

Structures—structures, that is, so imperfectly developed as to be of no apparent use to the organisms now possessing them, and yet structures which when fully developed, as in other related species, are of the greatest possible use. To refer again to the forelimbs of some of the higher animals, we find among the Amphibians, the Reptiles, the Birds and the Mammals that the typical number of their palm bones is five, and that the typical number of the sets of digital bones attached to them is also five. But this number, though it is never greater,¹ is often less, being reduced in many cases to four, three, two, and even one. But the most significant point is, that when we examine animals in which this sort of reduction has occurred, we frequently find that some of the bones in question have only partially disappeared—that is to say, though they are still in a sense there, they are in a quite rudimentary condition, and hence useless—a circumstance extremely difficult to account for on the old hypothesis that each species came into being separately. Thus if we compare the beaver, which like ourselves has the full complement of digits, with the hyrax, we shall find in the latter that, although the thumb or first digit has completely vanished, there is still a remnant left of the palm bone to which it must formerly have been attached. In the tapir, however, this, too, has vanished, so that now there remain only four palm bones and four digits. Turning next to the rhinoceros, we find that another digit with its palm bone has all but disappeared, leaving behind it just a small rudiment; while lastly in the horse the reduction of the digits has been carried to such an extent that only one of them is left, viz. that corresponding to our own middle finger. If, however, the horse's cannon bone is examined, which is the middle palm bone, two slender strips² will be found attached to its upper end, representing the two adjacent and fully developed palm bones which were once on each side of it. The accompanying illustration is intended to show the state of things as it exists in the above animals, as also in the camel, the pig, the two-toed sloth,

¹ Except among certain monstrosities.

² These are the so-called splint bones.

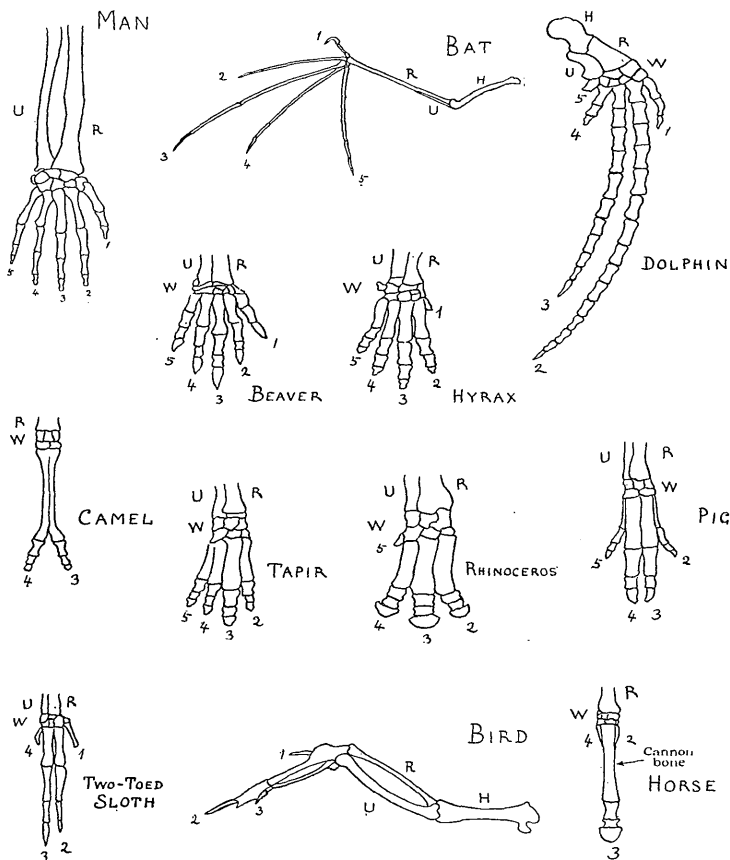


FIG. 51.—FORELIMBS OF VARIOUS ANIMALS SHOWING VESTIGIAL STRUCTURES.

H, Humerus ; U, Ulna ; R, Radius ; W, Wrist-bones ; 1-5, Digits.

and in birds. In birds it will be noticed that the palm bones, numbered 4 and 5, as well as the digits attached to them, are wanting, and that No. 1 is only very imperfectly developed.

As further examples of vestigial structures the following may be quoted :—

1. Whales, though they possess no hind limbs, still show deeply buried in their hind quarters the remains of the hip bones, to which these limbs must originally have been fastened.

2. The Australian Duckbill, a very primitive mammal, though it possesses teeth when it is quite young, sheds them at an early stage and becomes provided with a horny bill instead.

3. The Kiwi, a New Zealand bird, is quite unable to fly, as its wings are very imperfectly developed. This points to its being descended from birds which had properly developed wings, and were, therefore, well able to fly.

4. Traces of eyes in addition to the ordinary pair have been detected in certain fishes, amphibians and reptiles, and one such eye is supposed to be represented in Man and in the Mammals generally by the *Pineal Gland*, which is now sunk deep within the substance of the brain.¹ In certain lizards it is much more highly developed. It will be remembered (Chapter XVI, p. 219) that the retina, the most essential part of the eye, is formed out of what is really a protruded portion of the brain.

5. Man also possesses rudimentary tail bones, rudimentary muscles for moving his ears and his scalp, and a rudimentary third eyelid corresponding to the third eyelid in birds.

Among plants we notice precisely the same kind of phenomena. In the order of the *Scrophularineæ*, for example, we have the Mullein, which is provided with five typical stamens, although they are not all equally developed. In the Figwort one of them is reduced to a staminode—that is, to a barren stump no longer producing pollen. In the Snapdragon this stump has completely disappeared, although occasionally, with the help of a lens, one can detect a minute

¹ See fig. 27, Chapter XVI.

scale representing it low down in the tube of the corolla. In *Gratiola* not only has this stamen been suppressed, but two of the others have met nearly the same fate, while in the *Veronicas* these two have vanished altogether.

Under this head I may mention also those cases of so-called *Reversion* in which some vestigial structure regains its former shape and size, or in which a structure which has completely disappeared turns up again. Thus a horse will sometimes be born with one of its digits restored, or a human being with a distinctly projecting tail. Or the latter may develop canine teeth very much larger than usual, and strongly resembling those found among the anthropoid apes. Occasionally, too, as we have seen (Chapter XVI), the arrangement of the chief arteries will revert to the reptilian type.

III. *Succession in Time*.—We come now to the very important evidence derived from the study of the fossil remains of animals and plants buried in the rocks beneath our feet. These rocks are of two principal kinds, the igneous and the sedimentary. The former, of which the granites and the basalts are well-known examples, are the result of the cooling and subsequent solidification of what was previously molten material. It is useless, therefore, to look for any indications of past life in them. It is otherwise with the sedimentary rocks—the gravels, clays, sandstones, conglomerates, limestones and shales—which were deposited either in fresh-water lakes or on the ocean bottom. In these we find abundant animal and vegetable remains; and inasmuch as we know the order in which the rocks were laid down—for naturally the later rocks were superimposed on the earlier ones—we know also the order in which the various forms of animal and vegetable life appeared.

The total thickness of the sedimentary rocks has been estimated at about fifty miles, and they must have taken an enormous time to accumulate—according to Barrell, from 1200 million to 1400 million years. This period has been divided into five main sections, which, reckoning from the earliest times until now, have been named Archæozoic, Proterozoic, Palæozoic, Mesozoic and Cainozoic.

In the rocks of the Archæozoic age no actual fossils have been found, but it was probably then that the unicellular organisms—the Protozoa and the Protophyta—first arose. As their bodies consisted of soft parts only, they naturally did not leave any traces of themselves behind. In the Proterozoic rocks, which came next, there have latterly been discovered what appear to be the remains of sponges, corals, worms and crustaceans. At all events it is quite certain, from the great diversity of forms which characterise the period immediately following, that Life must already at that time have advanced a considerable way along its upward path.

<i>Geological Periods</i>	<i>Evolution of Animal Life</i>
CAINOZOIC (1).	MAN.
Pleistocene and Recent.	
Miocene and Pliocene.	
Oligocene.	Anthropoid Apes.
Eocene.	Mammals (higher). Birds with bills.
MESOZOIC (3).	
Cretaceous.	Snakes, Crabs.
Jurassic.	BIRDS (lower, with teeth). Highest Insects.
Triassic.	MAMMALS (lower).
PALÆOZOIC (6).	
Permian.	REPTILES.
Carboniferous.	AMPHIBIANS.
Devonian.	Fishes (higher), including Dipnoi.
Silurian.	CHORDATES. FISHES (lower).
Cambrian and Ordovician.	Insects.
PROTEROZOIC (4).	Sponges, Corals, Worms, Crustaceans.
ARCHÆOZOIC (6).	NON-CHORDATES. Proto- zoa.

Note.—The numbers after the main periods show their supposed relative durations.

The Palæozoic rocks have been divided into the Cambrian, the Ordovician, the Silurian, the Devonian, the Carboniferous and the Permian systems.

During the Cambrian and Ordovician periods almost

every variety of invertebrate life seems to have flourished, including several of the lower orders of insects. It is not, however, till we get to Silurian times that we find any decisive evidence of the existence of the great Chordate group. It was then that Fishes first appeared, but only those belonging to lower types, such as (1) Round-mouthed Fishes without proper jaws, answering to our present-day Hags and Lampreys; and (2) others which, although provided with jaws, resembled our modern Sharks, in that their skeletons were cartilaginous, not bony. These were succeeded in the Devonian period by Fishes much more advanced. They included among others the Dipnoi, or Lung-breathers, which prepared the way for the coming of the Amphibians in the Carboniferous age. According to some it was also during the Carboniferous age that Reptiles first appeared, although they have generally been referred to the following or Permian times.

The Mesozoic rocks, which were next laid down, comprise—again reckoning from below upwards—the Triassic, the Jurassic and the Cretaceous systems. The whole of this period was marked by the enormous development of reptilian life, which now spread itself everywhere and assumed a perfectly bewildering variety of forms. Some of them, huge repulsive-looking monsters, roamed the surface of the earth; others, such as the *Ichthyosaurus* and the *Plesiosaurus*, betook themselves, like their fishlike ancestors, to the waters; whilst the *Pterodactyls*, with their weird bat-like wings, gained possession of the air. Meanwhile, though to begin with they were but a feeble folk, the Mammals first dawned upon the scene—Mammals, however, belonging only to the two lowest orders, which either like the Duckbill lay eggs,¹ or like the Kangaroos and Opossums² bring forth their young in an immature condition. Their remains are first found in the Trias, and so also are the remains of most of the existing orders of Insects. In the Jurassic rocks, which followed, the earliest fossil bird has been unearthed, the famous *Archæopteryx*, with its long lizard-like tail furnished with pairs of feathers, with its curious claws

¹ The Monotremes.

² The Marsupials.

and with its conically shaped teeth. It was likewise in Jurassic times that the two highest orders of insects arose, namely, the Hymenoptera, to which the ants, the wasps and the bees belong, and the Lepidoptera, including the moths and the butterflies. In the succeeding Cretaceous times the birds had lost their long tails, but still retained their teeth. Crabs, too, made their appearance then, the highest forms of Crustacean life; also Snakes, which by their several vestigial organs and by the loss of their limbs, etc., clearly betray their descent from earlier and more perfectly equipped reptiles.

The Cainozoic rocks include the Eocene, the Oligocene, the Miocene, the Pliocene, the Pleistocene and the Recent. Eocene times were marked by the appearance of Fishes of a much more modern type, of Birds no longer toothed but provided with bills, and, most important of all, by the appearance of the Higher Mammals, in which the young are no longer brought forth in an immature condition, seeing that during a greatly extended prenatal period they are nourished by means of that remarkable structure, the placenta, briefly described in Chapter XV. It must be remembered, however, that in Eocene times none of the Mammals belonged to existing species, and that they had only partially diverged into those very clearly marked orders or divisions with which we are acquainted to-day. Moreover, there were many intermediate forms, as, for instance, between dogs and bears, cats and hyænas, tapirs and rhinoceroses. The Miocene period, and, according to Sir Arthur Keith,¹ the Oligocene period which preceded it, were signalled by the appearance of the Anthropoid Apes, and later, at the end perhaps of the Pliocene, by the coming of Primitive Man. Also, during the Pliocene, stags acquired their complicated antlers, rhinoceroses their horns and pigs their tusks. As to the Pleistocene and Recent periods it will be enough perhaps to state that Modern Man arose during the laying down of the former of these, and that he has since branched out into all the various races which inhabit the earth to-day.

¹ See his *Antiquity of Man*, the frontispiece.

Of course it is quite possible that, as the result of the further investigation of rocks in different parts of the world, fossils may yet turn up, proving the existence of this and that other group of animals at periods somewhat earlier than those given above. But even if that should happen, the broad fact would still remain that life on our planet has pursued a continually progressive course, although here and there, as with snakes, there may have been retrogression.

Now if the doctrine of Evolution be untrue, and we are to imagine instead that the various species of animals and plants arose independently of one another, in consequence either of an extended series of Divine acts or of an immense number of occurrences undirected by any intelligence, then on the first hypothesis how futile it would seem for the Almighty to have created species in one age only to wipe them out in the next, and on the second hypothesis how difficult it would be to account for the progressive order in which the various forms of life emerged upon the scene.¹

Again, if the various species of animals and plants were not genetically related, but arose independently, what do we suppose we should actually have witnessed, had we been present on the earth at the time of the first appearance of any one of them? Would it have been something like that which we find described in Ezekiel's vision (chap. xxxvii) when "there was a noise, and behold a shaking, and the bones came together, bone to his bone," only that in place of bones it would have been a coming together of particles of water and air and clay? But the very effort to picture to ourselves so extraordinary a scene at once tells us that it could never possibly have occurred. And yet if we refuse to accept Evolution, it must necessarily have occurred, and not once only at some far-distant epoch in the history of the earth, but over and over again down all the subsequent geological ages. It must have occurred, too, comparatively recently, for, as stated above, all our existing mammalian species have arisen since the Eocene beds were first laid down. Moreover, if modern estimates

¹ This latter point will be dealt with in the following chapters.

are correct, the period which has elapsed since then can only be about one-tenth of that which separates us from the Cambrian age, the rocks of which furnish us with the first decisive indications of life on our planet.

Lastly, there are at least two species of animals, viz. the horse and the elephant, whose pedigrees can be traced back with almost absolute certainty, seeing that we possess so many of the intermediate links connecting them with the past. Thus among horses we have that very primitive form known as *Eohippus* which flourished in early Eocene times—that is, according to Sir Arthur Keith, rather more than twenty thousand centuries ago.¹ It was of diminutive size, about 11 inches in height, with each of its forelimbs provided with four toes, or rather fingers, as well as with a vestigial thumb. It was followed later on in the Eocene by *Proterohippus*, 15 inches high, in which the vestigial thumb had completely disappeared. In the Oligocene period we find the remains of horses which had grown to be from 18 to 24 inches in height and, through the loss of another digit, had become three-toed only. Also, certain important changes had taken place in the structure of their teeth. In the Miocene age a number of other species arose exhibiting still further changes, till a little later, in the Pliocene deposits, we find horses which had attained a height of 48 inches, and in which two more of their toes were on the point of being suppressed. Lastly, we come to the modern one-toed horses, having an average height of 64 inches. But although they are one-toed, their vestigial splint bones point back, as previously said, to their many-toed ancestors.

A somewhat similar tale could be told of the elephant—how he gradually increased in size, at the same time turning his long and highly flexible nose into a trunk, and how he gradually lost all his front teeth except two, which became converted into tusks. Meanwhile his other teeth were undergoing certain remarkable modifications, as were also his jaws and the general shape of his head.

If, then, in the case of both the horse and the elephant it

¹ See his *Antiquity of Man*, the frontispiece.

seems to have been so clearly shown that the earlier species must have given rise to the later ones, there can be no reasonable doubt that the same holds true of all other animals besides, Man included, although, on account of the fragmentary nature of the geological record, we may not yet be in possession of more than a few of the missing links.

IV. *Geographical Distribution*.—Whatever view may be taken as to the manner in which species originated, it is plain that each must have appeared in some particular locality on the surface of the earth. From this locality, as from a centre, it must gradually have spread itself out over the area which it now occupies, and which is technically described as its *range*. Plants have their own methods of dispersal, which we need not here discuss, but in so far as animals are concerned, and especially the higher ones, their dispersal is principally brought about by their powers of locomotion. These powers vary, however, very considerably as between different groups. Thus we may compare in this respect birds and mammals with such lower forms of life as crabs and snails. Moreover, the spread of a species is always more or less limited by climatic conditions, as well as by the occurrence of natural barriers like great mountain ranges and wide stretches of sea. The last named are most effectual perhaps in the case of the larger mammals, the majority of which can only swim a very little distance from the shore and are quite incapable of aerial flight. Again, it is obvious that the area over which a species has succeeded in establishing itself has to a large extent depended on the time which has elapsed since it first arose.

Confining ourselves to mammals, let us consider the evidence in favour of Evolution, which is supplied by their geographical distribution. It will suffice if I refer to four special groups.

(1) *Lemurs*.—These form the lowest members of that most important of all the Mammalian orders, viz. the Primates, to which the monkeys, the baboons, the anthropoid apes and we ourselves belong. Of the lemurs—or rather the *true* lemurs—there exist at the present time some

six or seven different species ; but the remarkable thing about them is that they are all congregated together in one particular region of the earth, namely, in Madagascar and in the neighbouring Comoro Islands. Now on the supposition that these different species originated independently of one another, what account can be given of the curious fact that they should all have done so in the same general locality ? Why in Madagascar and in the Comoro Islands alone ? Why should not some of them at least have originated elsewhere ? On the Evolutionary theory the explanation, of course, is perfectly simple. These particular species are now found assembled together in the same region of the earth because they are genetically related to one another, they possess a common ancestry. Moreover, they have failed to spread themselves over any wider area, because since they first arose Madagascar has been effectually cut off from the great continent of Africa by that broad strip of sea, the Mozambique Channel, which they have been quite unable to cross. As a confirmatory piece of evidence there is this further fact, that in Madagascar the fossil remains of other lemurs have been found, most of them belonging to species which are now extinct, but which were obviously the ancestors of those which are living there to-day.

(2) *Sloths, Ant-eaters and Armadillos*.—These three groups of animals, all of which belong to the order of the *Edentates*, are restricted, like the lemurs, to one particular region of the earth, namely, to Central and South America. Again we ask, Why should these closely allied, very peculiar creatures be found only here and nowhere else ? Of the sloths there are two genera and three species ; of the ant-eaters there are three genera and four species ; and of the armadillos six genera and twelve species—that is, nineteen species in all.¹ Moreover, the same region has furnished a rich supply of fossil remains of precisely the same character—among them a gigantic armadillo known as the *Glyptodon*, and, still more important, a number of ancient forms intermediate in kind between the sloths and the ant-eaters, and presumably, therefore, closely allied to, if not actually iden-

¹ R. Lydekker in Harmsworth's *Natural History*, p. 859.

tical with, their common ancestors. The general conclusion to be drawn from these facts is, of course, the same as that set forth in the preceding paragraphs.

(3) *Tapirs*.—Of these there are only five species, four of which are peculiar to Central and South America, while the remaining one is limited to the Malay Peninsula and to certain adjacent islands in the East Indies. This at first sight would seem to suggest the idea that tapirs must have originated twice over and in two widely separated regions. Inasmuch, however, as their fossils have been discovered not only in the regions just referred to; but in North America, in Europe, and in other more northerly parts of the Asiatic continent, we gather that in former times they were more numerous and much more widely spread than at present. Owing probably to the competition of other and more perfectly adapted forms which have arisen since, they have now become restricted to the two entirely detached areas above mentioned.

(4) *Marsupials*—that is, the Kangaroos and their allies. It has already been stated that these first made their appearance in Triassic times, and that during the whole of the Mesozoic period they were, along with the Monotremes—which were an order lower still—the sole representatives of the Mammalian class. During that long period, so we learn from their fossil remains, they must have well-nigh covered the face of the earth. Now they are found only in Australia and in certain of its adjacent islands, where they have branched out into a multitude of families, genera and species; as also in South America, where they are represented, but in far fewer numbers, by the true Opossums. The probable reason for their present abundance and great variety of forms in Australia, as also for their absence in nearly every other part of the world, is that Australia with its adjacent islands had become separated from the Asiatic mainland previous to the evolution of the higher placental Mammals, with which, therefore, these Australian marsupials have never been obliged to compete.

Another argument can be based on the fact that, whereas in an island like Great Britain, which has frequently in the

past been joined on to Europe, we find quite a number of native Mammals, in other islands like New Zealand, separated by many hundreds of miles from any continent, we find none. The only exceptions to this in the case of New Zealand are certain bats and seals—mammals, that is, which unlike the rest have either taken to the air, being able to fly, or taken to the water, being able to swim. There is just one other mammal in New Zealand which might be suspected of being a native, namely, a species of rat, but this is known to have been introduced by Man in recent times. As for purely oceanic islands, like those in the middle of the Pacific, they necessarily neither have, nor ever have had, any indigenous mammals. The vast stretches of sea separating them from the mainland have always proved a most effectual barrier preventing the entrance of these animals.

Yet if we are to abandon the Evolutionary theory and to believe that every species has had an independent origin, why should not a few at least out of the many hundreds of Mammalian species have arisen in some of these oceanic islands? And again, why should not some of the higher, the placental mammals, likewise have arisen in the great island continent of Australia? On the other hand, if we accept the Evolutionary theory, then the facts above described, together with a whole host of similar ones relating to the geographical distribution of plants and animals, can quite easily and naturally be explained.

V. Embryological Development.—In order to understand this very important line of proof, let us suppose that on purely anatomical grounds we tried to arrange the principal classes of the great Chordate group in something like serial order, choosing for our criterion the various degrees of complexity in the structure of their hearts. In that case the order so arrived at would undoubtedly be as follows: the Lancelet, the majority of Fishes, the higher lung-breathing Fishes, the Amphibians, the Reptiles omitting the Crocodiles, then the Crocodiles and last of all the Birds and the Mammals.

But this order not only tallies in every essential respect

with the order in which, according to the geological record, these various classes of animals first arose, but it tallies also with the order in which, for example, in ourselves the various embryological stages in the development of the heart succeed one another. Thus, if I may repeat what I have said before,¹ the heart, to begin with, is, as in the Lancelet, just a simple tube; next, as in the Fishes, it becomes bent upon itself in the form of an , and is divided into two chambers, an auricle and a ventricle. Then as in the lung-breathing Fishes, the Amphibians and most of the Reptiles, there is the gradual appearance of a septum dividing the auricle into two; and finally, as in the Crocodiles, the Birds and the Mammals, this is followed by a similar division of the ventricle. But what is true of the heart, and, as we have seen,² of the ear as well, is true, broadly speaking, of all the other organs in the body; and it is precisely this remarkable correspondence between the embryonic and the geological records, combined with the facts of anatomical structure, which provides us with one of the strongest arguments in favour of Evolution. It is a correspondence, however, which from the nature of the case fails us in so far as it relates to the earliest stages of all, seeing that the first organisms to appear upon the earth—and from which all the later ones have been derived—had none of those hard parts, such as bones, teeth and shells, which are capable of being preserved in the fossilised condition. Hence for our knowledge of these earliest stages we have to rely on the embryonic record alone, which, inasmuch as every individual begins its development as a solitary cell, thereby proclaims the fact that the species to which it belongs must originally have been derived from some primitive unicellular form—in short, from a protozoon. Similarly, the morula and the gastrula stages, which most embryos have to pass through, point back to remote ancestors whose organisation was of the same simple character.³

When we consider the exceedingly short time which it

¹ Chapters VIII and XV, pp. 88, 192.

² Chapter XVI, p. 223.

³ Chapters XIII and XIV, see fig. 20, p. 180.

takes for one of the higher animals to undergo its development, as compared with the enormous period during which the species itself was being evolved, it need not surprise us to find that the embryonic record is often greatly abbreviated, several of the ancestral stages being either omitted altogether or very imperfectly represented. Also, to subserve special purposes, entirely new elements have often been interpolated in the developmental series which have nothing corresponding to them among ancestral forms. This applies, for instance, to the appearance in the development of the higher Chordates of such structures as the Amnion, the Allantois and the Placenta,¹ since not one of these has ever been possessed by an animal in its final, its adult state.

Hence, for the reasons just given, if we choose to denote the original evolutionary series by the letters *A, B, C, D, E, F, G, H*, etc., it may well happen that the embryonic series will run thus: *A, —, C, D, —, F, G (P, Q) H*, etc., in which *B* and *E* have dropped out altogether, and *P* and *Q*, quite new members in the series, have been inserted. The fact, however, that such differences between the two series frequently occur does not invalidate the embryological proof, seeing that by the comparison of the developmental histories of a large number of animals, it is in many cases possible to recover the true evolutionary order, in much the same way as it is possible by the comparison of the various MSS. of an ancient author to recover the original text.

There is another consideration which adds greatly to the force of the embryological argument. It is that the individual in its development by no means always pursues the most direct path to the attainment of its ultimate form, but often diverges, now in this direction and now in that, as though it were its intention, one might almost say, to become something quite different. Thus in the development of birds and mammals there comes a stage when a number of branchial clefts or gill-slits make their sudden appearance. True, they close up again almost immediately ;

¹ Chapter XV, see fig. 23, p. 198.

but how are we to account for this singular phenomenon except on the supposition that there was once a time when the common ancestors of birds and mammals were breathing with gills, just as all fishes are doing to-day? ¹ Or why does there come a stage when the main arteries immediately connected with the heart show by their number and arrangement so striking a resemblance to what is still found in fishes, although shortly afterwards several of them become aborted and presently wither away? ² It is, indeed, facts like these which supply some of the strongest evidence in favour of the Evolutionary Theory.

VI. *Certain Recently Observed Changes.*—I will refer to only two examples of these :

A. In the year 1880 in a garden at Shirley, near Croydon, where a number of wild poppies (*Papaver rhæas*) happened to be growing, there unexpectedly appeared among them a plant bearing flowers of quite a different kind—so different, indeed, as to cause it to be regarded, whether rightly or wrongly, as a new species. The seeds produced by this plant were subsequently sown, and gave rise to what have ever since been known as “Shirley poppies.”

B. Similarly, De Vries, the great Dutch botanist, observed the rise of what he believed to be no less than fifteen new species of the Evening Primrose.³ They were discovered in a field in which previously all the Evening Primroses growing there had belonged to the single American species, *Oenothera Lamarckiana*.

Putting together, then, all these different lines of proof, we conclude that species have not, as was formerly supposed, originated separately, whether by a series of isolated Divine acts or otherwise, but they have originated from one another by a process of Evolution, whereby all the different forms of animal and vegetable life are genetically interrelated and are thus bound together in one single all-embracing System. As we shall see, however, this by no means necessarily excludes the idea that the Divine agency may

¹ Chapter XVI.

² Chapter XVI, see fig. 24, p. 207.

³ See next chapter.

have been at work in the process all along. To such a conclusion, indeed, we may be forced to come, if all the usually assigned causes of Evolution should fail to give an adequate explanation of what has actually occurred. So in the next two chapters I propose to turn to this very important question.

CHAPTER XXV

THE CAUSE OF EVOLUTION

I PASS on now to a subject the importance of which it would be difficult to exaggerate, in view of the main object with which this book is written. We have seen in the preceding chapter how the fact of Evolution has been established past all dispute, as the result of the convergence of several distinct lines of proof. We have next to inquire as to the cause or causes of Evolution—causes sufficient to account for the transformation, for instance, however slowly it may have been accomplished, of some such simple form as the common *Amœba* into the form now so highly complicated in its structure and in its various functions as the human body.¹

In Chapter V I have already explained how, according to a certain well-known theory, the entire process of Evolution is to be attributed to variations of a fortuitous kind working in conjunction with natural selection; and how in consequence of this it has been thought wholly unnecessary to assume the existence of any Purposing Agent, to account for all those numerous purposive arrangements which are so characteristic a feature of plants and animals alike.

Now in so far as natural selection is concerned, the operation of which to a certain extent must be frankly acknowledged, we have to remember that its influence has all along been of a purely negative kind. It could not create; it could only eliminate, and to do so it had to wait till variations from time to time arose. Hence the question of the cause of Evolution clearly resolves itself into the question of the cause of variations. What we have now, therefore, to consider is whether the causes usually assigned

¹ See Chapter XII, pp. 138-141.

have been in themselves sufficient to bring Evolution about, apart from the guidance of some all-directing Mind.

If we grant for the moment that such guidance was given and that it acted, as we must conceive it to have done, in some peculiar manner on the germ-cells, that need not exclude the possibility of other forces of a more mechanical nature having acted as well. Moreover chance, or that which in our ignorance we so often speak of as chance, may have had its part to play in the matter too, as indeed is suggested to us by what we have learnt about the Mendelian laws. Hence, though we may be led to regard the Evolutionary Process in its broad outlines, and certainly in its ultimate aim, as the work of some Superior Intelligence, we may nevertheless freely admit that in many of its minor and less important details it has been due to influences of another kind.

Should this turn out to have been the case, then the history of Life on our planet might be compared perhaps to the gradual growth of one of our forest trees. For although in an oak, for example, the character of its flowers and fruit, of the shape of its leaves and of its entire internal structure, have been determined by the principle of life within it—by what I have elsewhere termed its psyche—yet the precise ultimate form of the tree, including the number, size, disposition and peculiar curvature of its branches, has been chiefly determined by its surroundings—by light, gravity, moisture, and by the manner in which it has been exposed to the winds of heaven. Again, when one of its buds, which would otherwise have shot out and grown into a big bough, has been nipped off by frost, or when, owing to lack of sufficient air and sunshine, it has only become very feebly developed, plainly we have something which is closely analogous to the eliminating effect of natural selection. Just then as the tree, when it has reached maturity, is the result of the play of both internal and external forces, so we may conceive it to have been in the case of the great Tree of Life, the larger and smaller branches of which correspond to the larger and smaller divisions of the animal and vegetable kingdoms.

From the purely theological standpoint it may possibly be objected to this that, if the supposed Intelligence which has been at work in Evolution is afterwards to be identified with the Supreme Power from whom the entire Universe proceeds, then it would seem scarcely congruous with our ordinarily received notions of Him, that His evolving activity should in any way have been limited by forces emanating from a physical order of things of which He has also been the Originator. The objection, however, disappears if we conceive of the limitation in question as having been self-imposed, and especially if, as we shall see later on, some far-reaching ulterior purpose was to be accomplished by it. We ourselves often consent to put certain restrictions on our own liberty of action, as when, for instance, in playing a game we enter upon it on the tacit understanding that we intend to abide by its rules. Nor should we think of doing otherwise, even if the game were of our own devising.

But, to proceed, whenever a variation appears, it necessarily implies that some change of a more or less profound character must have taken place in the germ-cell of the individual exhibiting it. The question is, however, Does such a change arise spontaneously, as it were, within the germ-cell—or in one of the reproductive cells which have united to form it—or has it been induced by some important change external to it, which has been previously effected in the *body* of one or other of the parents? In a word, in reference to the germ-cell, is the cause of variation intrinsic or extrinsic? If extrinsic, then the exceedingly knotty point is immediately raised as to whether characters acquired by individuals during their lifetime can possibly be passed on in this manner to their offspring—a matter on which, as is well known, authorities have differed very widely indeed. Some, like Darwin, Wallace, Herbert Spencer and Haeckel, have fully believed in the transmission of acquired characters, whereas Weismann and his followers, including men like Sir Francis Galton and Sir Ray Lankester, have denied its possibility, referring all variations to intrinsic causes only. More recently, however, as we shall see in the next chapter, there

has been a tendency to revert to what may be regarded as the earlier position.

As it would be sheer presumption on my part to hazard any opinion one way or the other on this much debated subject, my best plan perhaps will be to consider First, the alleged intrinsic causes of variation, and Secondly, the alleged extrinsic ones, with a view to finding out whether on either supposition it is possible to account for the actual course which Evolution has pursued, if all thought of a Superior Directing Intelligence is to be excluded.

(A) *Alleged Intrinsic Causes*.—These are usually conceived of as entirely fortuitous, and as having given rise to purposive structures only because, as explained in Chapter V, natural selection has incessantly been at work, weeding out all variations which have failed to confer on the organisms exhibiting them certain marked advantages. Now variations, whatever may be thought as to the mode of their origination, have been divided into two main classes, viz. (a) *Fluctuations*, and (b) *Mutations*—a distinction which has only come into general use since Darwin's time. The first of these classes consists of variations which are comparatively slight. They are continually occurring in all organisms, and are the result, it is supposed, of certain slight corresponding changes in the germ-cells. Mutations, on the other hand—occasionally described as “sports”—are of a far more pronounced character, and are regarded as so many definite steps or jumps forward in the general course of Evolution. They have been attributed to changes in the germ-cells of a much more fundamental kind, and besides, they differ from fluctuations in that they are discontinuous and take place as a rule only at wide intervals of time apart. It will be well, therefore, to consider these two different classes of variation separately.

(a) *Fluctuations*.—Though there can be no doubt whatever as to the occurrence of these, the following are some of the objections to the idea that they are capable in themselves of bringing Evolution about.

(1) In the first place it is difficult to believe that changes of so slight a character could afford sufficient material for

natural selection to work on. The advantages conferred by favourable variations must, on the purely mechanistic theory, be of an appreciable kind, if they are really to add to an organism's chance of survival.

(2) For members of one species to be transformed into another—even should the two species not greatly differ—a considerable number of such slight variations would have to take place, and, what is still more important, for them to have any cumulative effect it would be necessary that they should all take place in the same direction. But what is there to compel them to do so if they are merely the result of chance? Of course, should it turn out that variations are to any extent due to some sort of continuous action on the part of the environment, then such sameness of direction—*Orthogenesis*, as it is called—might receive perhaps an explanation. But in that case the cause would be an extrinsic one, and in the present chapter it is only intrinsic ones which we are considering.

On the general subject of orthogenesis it may be well here to quote from Parker and Haswell's standard work on Zoology.¹ Its authors remark: "This definiteness of direction of Evolution is a fact in nature of which there is evidence on all sides. In nearly all groups, and nearly all systems of organs, there is evidence of progressive development, such as cannot be supposed to be due simply to the fortuitous appearance and selection of the Darwinian variations."

(3) In the case of an organ so elaborately constructed as the human eye,² with all its delicate adjustments and with every part dependent for its right functioning on all the rest, the difficulty is enormously increased of believing it to be the result of just these small, very inconspicuous variations. For we have here not merely one series of changes all taking place in the same direction, but a number of such series *concurrently taking place*, and in such a manner as by their conjoint action to produce that highly efficient piece of optical apparatus by means of which we see. But

¹ *Textbook of Zoology*, vol. ii, p. 666; but see the whole passage.

² See Chapter X.

how is this extraordinary concurrence to be explained if it is to be put down simply to chance? It is reported of Darwin that even to the last he found it difficult to think of the eye without its giving him a "cold shiver."¹

(4) That variations of the kind which we are now considering should have given rise to new species, appears to have been finally ruled out of court by certain experiments performed in recent times by Johannsen on the kidney bean, by Agar on *Simocephalus*—a species of Crustacean—and by Jenkinson on the slipper animalcule. These experiments seem quite conclusively to show that although fluctuations may possibly be due to what we commonly describe as chance—for they follow the law of chance distribution—they are only quantitative in kind, and, what is far more important, they are strictly confined within certain limits.

To demonstrate this last point it is necessary to choose plants or animals which are capable of self-fertilisation, since it is only by this means that complications arising from double parentage can be eliminated. Suppose, for instance, as in Johannsen's experiment, we self-fertilise a bean plant and afterwards weigh the beans thus produced. Some, of course, will be heavier, and others lighter than the rest, but they will all hover, so to speak, about a certain mean value. Let us now take one of the beans which weigh most, sow it, and when the new plant grows up and blossoms, see that once more self-fertilisation takes place. This will supply us presently with a second set of beans whose weights we shall naturally expect to show a mean value considerably higher than that obtained before. In this, however, we shall find ourselves mistaken. On the contrary, the mean value will scarcely have been raised at all. In other words, the beans produced by the big bean will be scarcely any bigger than those produced by the original bean, which was much smaller. Of course, in a mixed lot of beans, as obtained from an ordinary seedsman, there will probably be present quite a number of different strains, each as regards weight having its own mean value. If, now, such a mixed lot were

¹ Wallace, *Darwinism*, p. 130.

sown and the seedlings allowed to grow up together and fertilise one another indiscriminately, and if, further, through several generations we were to keep on selecting for seed those beans which were the heaviest, naturally we should little by little get rid of all the lighter strains. Thus perhaps we might be beguiled into thinking that by our selection we had brought about some deep-seated change, and that we were on a fair way towards the production of a new species. In drawing such a conclusion, however, we should be entirely wrong, for experiments like the one just described clearly show that Evolution cannot be due to variations of this kind, inasmuch as their range is a definitely restricted one, and any species affected by them always tends to return to its original, its normal condition. And if the variations in question are thus unable to transform a species into another closely resembling it, still less are they able to give rise to that immense diversity which exists in both the vegetable and the animal kingdoms as between the various genera, orders, classes, etc. They are, as the appropriate name bestowed on them signifies, simply "fluctuations."¹

(b) *Mutations*.—These, as already stated, are supposed to occur only at certain intervals, but when they do occur to be of a much more pronounced character. Evolution, if the result of fluctuations, might be compared to movement up a fairly smooth inclined plane; whereas if the result of mutations, it might be compared to ascent up a flight of steps, in which the steps are at considerable distances apart. Among alleged instances of mutation we have the Shirley poppies and the various new sorts of Evening Primrose referred to at the end of the previous chapter. Also, a large number of mutations are described as having taken place in the case of *Drosophila*, the fruit-fly. Now, aside from all other considerations—considerations to which we shall return presently—it is quite a moot question as to whether any of the mutations just mentioned have really given rise to anything more than a number of new varieties.

¹ "The belief that substantial genetic change commonly accrues by summation of impalpable differences has been generally abandoned as devoid of evidential foundation."—W. Bateson, *Encyclopædia Britannica*, vol. xxxi, p. 911.

Professor MacBride, in his article on "The Present Position of the Darwinian Theory,"¹ calls attention to the following points :—

(1) A mutant differs from the parent stock in one or two particulars only, whereas a couple of closely allied natural species differ from one another in a large number of particulars.

(2) The majority of hitherto observed mutants are recessive in character ;² they exhibit defect rather than progress, and several of them are of a distinctly pathological order. Even the few dominants among them frequently show signs of monstrosity.

(3) Mutants not only breed freely with one another, but they produce fertile offspring, whereas closely allied natural species will only breed together with difficulty, and, when they do so, their offspring are generally infertile.

From the standpoint, however, from which this book is written, it is quite immaterial whether the changes which issued in the production of new species *resembled*, so far as outward appearances went, fluctuations or mutations, *i.e.* were either little or great. Changes of some sort there must necessarily have been for Evolution to have taken place at all. So the really important question before us is this : Were such changes, or were they not, the result merely of chance ?

To answer it, let us pass in review some of the principal facts as set forth in the earlier portions of this work.

I. First, there are the Physiological facts ; and here I will ask the reader to turn back to the summaries given at the end of Chapters VI–XI, as also to re-read the chapter following them entitled "Retrospect." I endeavoured in those chapters to describe some of the marvellous purposive arrangements which are found to-day in the bodies more particularly of the higher animals, including of course ourselves. Special attention may be directed to those sections dealing with (1) the provision of the various digestive juices and the several ways in which their secretions are stimulated ; (2) the manner in which what may be termed the "respira-

¹ See *Science Progress* for July 1923.

² See Chapter XIX, p. 265.

tory problem" has been solved; (3) the means by which the blood is made to circulate, and always in the required direction—outwards from the heart through the arteries to the capillaries, and back to the heart through the veins; (4) the highly complicated mechanism of the eye and all its wonderful adjustments; (5) the means by which in man speech has at last been rendered possible; (6) the utilisation of the different kinds of tissue for the construction of the different organs and systems; and (7) the harmonious working together of these systems, as shown more particularly by the manner in which they come to the assistance of one another, whenever an unusual demand is made upon any one of them. This is well illustrated by what happens when a man suddenly begins to walk up a steep hill or engages in any form of violent exercise. It immediately gives rise, of course, to increased oxidation in his muscles and to the pouring forth into his blood of an excess of carbon dioxide. But that this excess may be got rid of, a nervous message is at once dispatched from the lower part of his brain to the diaphragm and the chest muscles, bidding them hurry on the breathing. The heart also receives a message, urging it to beat faster, and the liver is directed to allow more sugar to pass into the blood, as an additional quantity is now needed to make good the waste going on in the muscles. Thus whenever the motor system happens to have extra work thrust upon it, the respiratory, the circulatory, the digestive and the nervous systems all rise to the occasion and are ready to lend, so to speak, a helping hand.

Now all this extreme complexity of interrelated functions, as well as extreme complexity of structure, is a state of things which can only have arisen—if Evolution be true—by means of a vast succession of changes which must, outwardly at least, have resembled either fluctuations or mutations, or possibly both. To begin with, the only existing forms of animal life were of the lowly protozoan type—minute, unicellular organisms without stomach, without lungs, without heart, without brain, without skeleton, and without any of the higher organs of sense; and yet out of these exceedingly simple forms have been derived in the course of ages all

that we find present in the way of complicated organisation in the animal world to-day. Instead of a single cell we have now, as in the case of Man, myriads of cells constituting the body, and these have become differentiated in all manner of ways and have been built up into tissues, organs, systems and system-groups, each having its own purpose and its proper location in the body, and yet all of them so perfectly co-ordinated as to enable the organism as a whole to maintain itself alive, to enter into ever-increasing relations with the environment and to reproduce—once more by means of a single cell—its own kind. This is the astounding miracle for which an adequate explanation is imperatively required, and it appears to me at least absolutely incredible—for the reasons some of which have just been given—that it should have been brought about by any succession of mere chance happenings, or by any conceivable combination of blindly working purely physical and chemical forces. How, too, if there had been nothing at the beginning of things of the nature of Intelligence, did intelligence at last arise and reach that high degree of development which we find in Man?

II. But to the facts just stated we have now to add all the Embryological ones, as set forth in Chapters XIV–XVI, and of which perhaps the most striking are the following : (1) The extremely elaborate process which is gone through every time a cell divides,¹ including the formation of the achromatic spindle, the longitudinal splitting of the chromosomes, and the allocation of them afterwards in equal numbers to the two new daughter-cells ; (2) the infoldings and outfoldings and other movements of entire layers of cells, in order to form the various organs of the body ; (3) the differentiation of these cells into bone, muscle, nerve, connective tissue, etc., according to the requirements of the various parts of the body ; (4) the ordering of events in such a way as that each organ comes to be of the right shape and size and to occupy its proper position, besides being

¹ “ If a motor-car were of itself to divide into two motor-cars it would not be more extraordinary than the division of a cell.”—R. C. Macfie in *The Romance of the Human Body*. See fig. 18.

plentifully supplied with blood-vessels and nerves ; (5) the remarkable course taken in the development of such special organs as the heart, the eyes and the ears ; (6) the development of bone, and the provision made for its subsequent growth in both length and thickness ; (7) the manner in which the spinal nerves sprout out from the spinal cord and thread their way, in spite of all obstacles, to their proper destinations ; (8) the peculiar provision made among the higher Chordates for the due nourishment of their young previous to hatching or birth by means of those temporary structures, the yolk-sac, the allantois and the placenta ; and (9) among mammals, the change which takes place at birth in the general course of the circulation, and the curious little modifications in structure by which this change is effected.

How are all the above facts, or how is any one of them, to be accounted for, if the changes which gradually gave origin to them were simply of a fortuitous nature ?¹

There is one instance which appears to me to be peculiarly difficult to explain on any such hypothesis. In Chapter XXII, when treating of the "cortical retina," I remarked on the different arrangement of the nervous fibres in the optic chiasma, according as an animal possesses panoramic or stereoscopic vision. In the former case, illustrated by the guinea-pig and the rabbit, all the fibres in the optic nerves cross over in the chiasma to the opposite side, whereas in the latter case, illustrated by the carnivores, the anthropoid apes² and Man, only one-half of them do so. The purpose of this is evidently, as I then explained, to secure in both cases a spatial correspondence between the

¹ Dr H. F. Osborn, Professor of Zoology in the Columbia University in New York, remarks on this point : "The net result of observation is not favourable to the essentially Darwinian view that the adaptive arises out of the fortuitous, but is rather favourable to the hypothesis of the existence of some quite unknown intrinsic law of life which we are at present totally unable to comprehend or even to conceive." And again : "The nature of the law which on the whole appears to be *purposive or teleological in its operations* is altogether a mystery which may or may not be illumined by further research."—*Encyclopædia Britannica*, vol. xx, p. 591, 11th ed. The italics are mine.

² The anthropoid apes include the Orang-utan, the Chimpanzee and the Gorilla.

different elements in the cortical retina and the different points in the external scene. It is necessitated by the fact that the image produced by any convex lens—such as the lens of the eye—is not only inverted, but is turned about in such a manner as to cause the right half of the image to form a picture of the left half of the external scene, and *vice versa*.¹

Now there is every reason to believe that among the Chordates all vision was originally of the panoramic kind, and that therefore stereoscopic vision was an arrangement which was afterwards, so to speak, grafted upon it. But for this to be effected two things were necessary. First, the eye-sockets had to be brought round more and more to the front of the head, so as to render the axes of the eyes more and more parallel; and secondly, *inside the skull and simultaneously with these changes* there had to be a complete re-arrangement of the fibres entering into the composition of the optic chiasma and of the optic tracks. Now it is the *concurrence* of these two quite distinct sets of changes which is the marvellous thing—a concurrence apart from which stereoscopic vision could never have been attained.

Further, although the optic stalks and the chiasma make their appearance at quite an early stage in the development of the eyes, they do not contain at first any nerve-fibres. The latter arise a little later on, and are really the axons of certain nerve-cells situated in the retinas. From these cells the fibres gradually work their way backwards in the direction of the brain, and on reaching the chiasma cross over either completely or in part as the case may be. From this we learn that when in the evolution of stereoscopic vision those changes were in progress which slowly brought the eye-sockets round to the front, *at the same time* certain fibres which had hitherto crossed over in the chiasma ceased to do so and took another direction. But how is a concurrence of this kind to be explained—and one so evidently for the sake of realising a definite purpose—if all variations are to be attributed to chance?

(c) *Variations due to Amphimixis*.—As these are also in-

¹ See figs. 48 and 49, pp. 318, 319.

trinsic in character and were made much of by Haeckel, this would seem the proper place in which briefly to refer to them. By amphimixis is meant that intermingling of the hereditary elements which is one of the results of the union of the sexes. We have seen¹ that in the formation of the reproductive cells a stage is reached when the materials contained in the chromosomes undergo very considerable re-arrangement. Hence the spermatozoa and ova, as regards their hereditary potentialities, are by no means all alike. Moreover, by the subsequent union of the sexes still further variety is introduced, owing to the great number of possible combinations. And this it is, no doubt, which accounts for many of the minor differences which are often displayed by the various members of the same family.

Now although we may be prepared to admit that these particular variations—if indeed they deserve the name—are almost certainly due to chance distribution—for the Mendelian laws would seem to compel us to this belief—it is quite another thing to attribute to them the rise of new species. All that in any case can be produced by such changes is a number of fresh combinations of the same set of identical elements—elements all slightly differing from one another, but whose differences must somehow have arisen previously. With what caused them to arise previously amphimixis can, of course, have had nothing to do, and yet, unless they had arisen previously, no fresh combinations would have been possible; amphimixis would have had no materials upon which to work.

To sum up, it may be said that our discussion of the various alleged intrinsic causes of Evolution has revealed to us their entire inadequacy for that purpose, so long as we attribute them to mere chance or to certain blindly working utterly unknown forces, instead of referring them to the continually exerted influence of some Unseen Directing Power. In the next chapter we shall proceed to the consideration of the alleged extrinsic causes of Evolution.

¹ See Chapter XVII, p. 233.

CHAPTER XXVI

THE CAUSE OF EVOLUTION (*continued*)

WE have now to consider—

(B) *The Alleged Extrinsic Causes.*—Although the efficiency of these has been seriously called in question, it must of course be allowed that influences of an external kind may often affect the development of the individual and produce certain changes in it. The development, for instance, of an unborn child must necessarily depend to some slight extent on the state of health of the mother, and on her ability to supply it during the months of pregnancy with the required nourishment. Also, previous to that, we must suppose, in the case of both the parents, that their general vigour or the reverse can scarcely be without its effect on the reproductive cells, while the latter are in process of formation. Indeed, it is quite possible that some of the fluctuations referred to in the last chapter may be due to causes of this kind.

It is obviously, however, quite a different thing to assume that, because a certain change has been effected in a particular part of the body of one of the parents by some external cause, this will so influence the generative organs as to make them produce ova or spermatozoa eventually giving rise to offspring, in which the same change will be observed and in precisely the same locality. Now it is this assumption which Weismann and those who hold with him have so persistently denied, but which others, on the strength of certain experiments, like those not long ago performed by Dr Kammerer, are nowadays inclined to accept. For an account of these experiments I must refer the reader to Professor MacBride's article in *Science Progress* for July 1923, as also to a paper by Dr

Kammerer himself published in *Nature*, May 12, of the same year.

Assuming, then, for argument's sake that it *is* possible for acquired characters to be transmitted, and that, therefore, extrinsic causes may have had some part at least to play in Evolution, this is tantamount almost to saying that such causes must in the last resort be referred to the environment. In other words, the environment must be supposed not only to act negatively by weeding out all undesirable variations—*i.e.* by Natural Selection—but positively by itself becoming the cause of variations, although in what precise sense "the cause" has still to be considered.

Now there are three different ways in which we may conceive of the environment as so influencing an organism, as to bring about certain changes in it, irrespective of whether these changes are afterwards transmitted to its offspring or not.

A. First, the environment may act upon it in a purely mechanical way, the organism all the while remaining passive. Thus a falling beam may leave behind it certain lifelong traces, or a limb may be permanently removed by the surgeon's knife. In all such cases, however, there is not the slightest evidence to show that the effects so produced are passed on to the succeeding generation. Compare with this what was said in Chapter XVII about the tails of mice and the feet of Chinese women.

B. Secondly, the influence exerted by the environment may be such as to evoke on the part of the organism a more or less active response which in time may give rise perhaps to a new variation. Under this head we may put the supposed effects of Use and Disuse, including Effort.

In so far as Disuse is concerned, it clearly can originate nothing; it can only reduce, and possibly sometimes get rid of, structures which have been already evolved.

On the other hand, Use, and especially the vigorous exercise of particular organs, may lead to an increase in their size, and occasionally perhaps to a multiplication of them; and these results *may* conceivably be passed on. It has even been suggested somewhat humorously that the

inordinate length of the giraffe's neck, which contains the same number of vertebræ as our own, may have been brought about by the continually renewed efforts of these animals to reach up to, and pluck off, leaves from higher and still higher branches. That there may be a certain amount of truth underlying notions of this sort may be allowed. All the same, any changes of a permanent and transmissible kind, which may possibly have been effected by such means, can only have been quantitative; they can never have originated new structures or added to their complexity, and it is precisely their origination and increasing complexity, as Evolution went on, which call so loudly for explanation. Again, we have to consider plants which, just like animals, though not to the same extent, have progressed enormously in both their internal and external organisation; and yet obviously in their case there can be no question of attributing such changes as have occurred in them to any sort of effort. Once more, it is exceedingly difficult to understand how even in animals effort could possibly account for the rise and the subsequent development of those extremely complicated internal organs which, like the heart, the blood-vessels and the liver, stand in no direct relation with the environment and are so entirely independent of any voluntary control.

The conclusion, then, at which we arrive is that Use and Disuse and the putting forth of Effort can only have played a very subordinate part among the causes of Evolution. They could not have originated, as I have said, any new structures, and especially the more deeply seated ones, and as to those which had been previously evolved, the most which they could have accomplished would have been to strengthen or enfeeble them, and in some cases perhaps to have caused a multiplication of them. Effort, moreover, could have had nothing to do with the evolution of Plants.

C. Thirdly, the environment may be supposed to have acted upon organisms in such a way as to evoke from them certain non-voluntary responses of a much more profound kind, and these, it has been thought, may gradually have brought about those important modifications or variations

which led in time to the production of new species. A theory of this kind has been propounded by M. Bergson in his *Creative Evolution*;¹ but if, as seems probable, the truth lies somewhere in that direction, the environment can scarcely be regarded as the cause of the variations, but rather as providing the occasions for their occurrence. Now between cause and occasion there is a considerable amount of difference. If I take a handful of sweet chestnuts and roast them before the fire, the heat of the fire is the cause of their being roasted; but if I bury them in the soil and in due time they grow up into chestnut trees, the cause of their doing so lies in themselves; the soil and its moisture, the fresh air and the light of heaven, have simply provided them with the occasion for revealing what was already implicitly contained in them. So it may also have been in the part played by the environment in the Evolution of Life upon our globe. The environment may simply have furnished it with those necessary stimuli, in response to which it gradually elaborated all those marvellous complexities of organic structure and of functional inter-relatedness which distinguish the world of living things to-day. On the other hand, if we are to conceive of the environment—endowed merely with the ordinary physical and chemical properties—as being *in itself the cause* of what occurred, the whole thing becomes quite incomprehensible.² One can understand how light, after passing through the lens of the eye, should paint a picture of the outward scene on the retina placed as a screen at the right distance behind it; but one cannot understand how light, by merely falling on the external surface of the body, could possibly have produced the eye itself with its lens and its screen and with all its wonderful focussing and other highly elaborate arrangements; still less, how it could gradually have awakened the sense of sight in animals previously unpossessed of it. It would be like crediting light with the

¹ P. 92, English translation.

² "We are utterly ignorant of the manner in which the idioplasm of the germ-cell"—i.e. practically the chromatin material—"can so respond to the influence of the environment as to call forth an adaptive variation."—E. B. Wilson, *The Cell in Development and Inheritance*, p. 434.

invention of the photographic camera and, what is more, with the production of sensitive plates—so sensitive, indeed, as that in some mysterious way they could become conscious of the pictures thrown upon them.¹ Neither by similar means could sounds have given rise to the ear and to the sense of hearing, and to all the pleasure and various emotional effects awakened in us by good music.

If, however, it be true that the environment with its purely physical and chemical properties has only helped to bring Evolution about by furnishing occasions to which Life in some inscrutable manner has responded, are we not, in view of the purposive character of these responses, driven once more to seek for the cause of Evolution in something which is of an essentially psychical nature? Especially does this conclusion seem forced upon us when, as we have just seen, not only have such organs as eyes and ears been evolved, but the subjective faculties corresponding to them, namely, sight and hearing. As I pointed out before, it is precisely by means of these two senses that practically all our knowledge of the external Universe has been acquired. Yet how can *knowledge* have issued at last out of matter originally possessed of only physical and chemical properties? Again, apart from sight and hearing, and I may add smell, the Universe would have remained little more than a kind of skeleton, for it is we who with the assistance of these senses of ours have endowed it with all the myriad hues and innumerable scents and sounds of what we commonly speak of as Nature.² The external world, indeed, in so far as Science can tell us anything about it, consists simply of an immense concourse of incredibly minute particles, all of them in a state of swift and incessant motion, and, in strict obedience to certain laws, giving rise to an endless number of continually changing configurations—some of them, like atoms and molecules, so small as to be far beneath the range of the most powerful microscopes, and others, like the “giant” stars, so vast in their dimensions as to exceed by

¹ In the case of *Porichthys* (see Chapter XII) was it the absence of light which was the cause of the production of its photophors?

² See Chapter XXI, pp. 295, 296.

many thousands of times our own sun.¹ But in itself the world as revealed by Science is devoid of all light and sound. It is we who out of our own internal (mental) resources have added to it the sunshine and shadow, the colour, the warmth, the melody and the fragrance, which have transformed it into the world in which we actually live—that intensely real world which supplies us with practically all the motives for our conduct, and which has been in every age the theme and inspiration of the poet and the artist. But how has it come about, I would ask, that at the end of the Evolutionary Process such results should have been attained, if at its beginning there had existed nothing more than that merely skeleton Universe of swiftly moving infinitesimal particles, which is all that Natural Science makes known to us? ² And the argument just employed applies equally, I may add, to the alleged intrinsic causes of Evolution which were discussed in the previous chapter, just as the argument employed there applies equally to the alleged extrinsic causes.

There is, moreover, in connection with the latter, as already said, a still further difficulty, so long as we cling to the belief that everything which relates to life is going to be explained in terms of mechanism. For grant, as experiments by Dr Kammerer and others have apparently shown, that the environment is somehow able to evoke responses giving rise to certain transmissible modifications, there still remains the problem,—By what conceivable kind of *mechanism* can modifications thus produced so act upon the germ-cells, as to make them develop into individuals in which the same modifications shall reappear, and in the same parts of the body? *Hormones* do not in the least help us here to overcome the difficulty, for a hormone, like secretin, for example,³ is simply a substance of a chemical

¹ As, for example, the star Antares in the constellation of the Scorpion, the diameter of which is said to be greater than that of the orbit of Mars. See G. E. Hale, *The New Heavens*, p. 57.

² Prof. A. N. Whitehead has described as “a disastrous error, the scientific creed that matter in motion is the one concrete reality in Nature; so that æsthetic values form an adventitious, an irrelevant addition.”—*Science and the Modern World*, p. 254.

³ Chapter VIII, p. 92.

nature which, formed in a particular part of the body and afterwards conveyed by the circulation to some other part, calls forth a certain definite reaction. But in the case which we are now considering we should have to suppose that, whenever, as the result of external causes, a new structure happened to arise or some new complexity in an already existing structure, a corresponding hormone simultaneously arose, endowed at once with the mysterious property of affecting the generative cells in the manner above described. Now it is difficult enough to conceive how the ordinary action of hormones can be explained mechanistically, but it would be ten times more difficult in the case of any action such as that which I have just imagined.

As the result, then, of our discussions in this and in the previous chapter, the general conclusion to which we seem to have been led is that the usually assigned causes of variation and, therefore, of Evolution are in themselves quite insufficient to account for what has actually happened.

We find ourselves, indeed, in relation to this great question in almost exactly the same position as when, at the end of the chapters entitled "In Search of an Explanation," the conviction was thrust home upon us,¹ how hopeless it was to try and account for what occurs in the course of individual development by any merely mechanistic theory. And just as then, so now, we seem compelled to postulate Something which in its deepest essence is of the nature of Intelligence. Behind the phenomena of Life, as displayed both by the single organism and by that vast genealogically related Whole consisting of all the plants and animals which have ever flourished on the earth, there stands That which is absolutely inapprehensible by our outward senses, but which, because of its visible and unique results in the world of so-called matter, is closely akin to that which in ourselves foresees and purposes and carries purposes into effect—in a word is intelligent.

But is this Intelligence to be conceived of as being One or Many? And again,—Is it Intelligence which, so to speak, is fully awake and clearly conscious, therefore, of

¹ Chapters XIX and XX.

what it is about, or must we think of it as lapped in some sort of dreamless slumber, and hence in merely blind and blundering ways bringing events to pass ?

As to the latter of these two questions, it surely stands to reason that with an Intelligence thought of as unconscious, or with any number of such intelligences, we are practically no better off than when we first set out on our inquiries. An unconscious mind knows nothing of either present, past or future ; it can look neither before nor after, and is quite incapable, therefore, of devising anything or labouring for its ultimate realisation. Hence a Philosophy of the Unconscious like that of Schopenhauer and his followers is not one in which we can possibly rest ; nor does Bergson's *élan* seem any the more satisfying. The Mind which is to account for Life and for Evolution and for all that they imply must necessarily be a Mind in full possession of itself.

But to revert to the other question, viz. Are we to refer the Evolutionary Process to the action of a Single Intelligence, or to that of many ? That the first of these alternatives is the only one admissible seems clear from the fact that, in spite of all the infinite variety displayed by the organic world, the Life-system of our little planet is essentially one, all its members being genetically related to one another. But this, its unity, points back to unity of origin. Also, we are led to the same conclusion when we reflect on the progressive character of Evolution, which has apparently been striving all along for certain definite ends, and more especially for the final emergence of Man gifted with all his wonderful and unique faculties. True, there are some outstanding cases of retrogression which might tempt us perhaps to think otherwise ; but they only serve to emphasise by way of contrast the well-nigh universal progressiveness elsewhere observed. They may be likened perhaps to those backward eddyings often seen in the side pools of some swift mountain stream, whose onward flowing current is here and there temporarily diverted by the big boulders strewn along its bed.

Granting, however, that Life, as it has been evolved on

our little planet, can only be explained by referring it to a Single Intelligence, we should not be justified on the evidence hitherto considered, in identifying it straight away with that Supreme Mind who, according to monotheistic belief, has been the Maker of all things in heaven and earth.¹ The very important question thus raised is one to which I shall have to return in the following chapters. Meanwhile, let us see what would be implied if we adopted a certain provisional hypothesis to which the facts might possibly seem at first to lend countenance. Let us suppose that the Superior Intelligence, who has been responsible for the introduction of Life upon our planet and for its subsequent evolution, is after all only a Being of a finite sort, but One who has nevertheless so manipulated the forces and the materials of the inorganic world, as to produce out of them all that rich variety of animal and vegetable forms which both now and in the past have appeared upon the earth. Now what among other things would such an hypothesis imply?

In the first place, it would imply on the part of the supposed Intelligence a longevity compared with which the brief span of human life would shrink into utter insignificance. Over against our petty threescore years and ten we should have to set that enormous period during which organic Evolution has been running its course.

Again, it would imply on the part of such an Intelligence the most minute and exhaustive knowledge of all the necessary conditions under which alone it would be possible, with any prospect of success, to launch into a world like ours an Evolutionary Process which was to extend over so immense an interval of time.

Added to this, there would have to be a complete knowledge of the already established laws of the inorganic Universe—the laws of light, of heat and of electricity, and of those which relate to energy and its manifold transformations. It would likewise mean a perfect acquaintance with the properties of the different chemical elements and, what

¹ Especially is this the case in view of the colossal scale on which, as we now know, the Universe has been constructed; but see next chapter.

is more, with those properties hitherto non-existent which would come into being, as the result of the building up of the atoms of these elements into those highly complex compounds described in Chapter III. It would have, for example, to be foreseen that out of that black solid substance known as carbon, and those two invisible gases, oxygen and hydrogen, it would be possible to construct such substances as sugar, starch, glycogen and the various fats, and with the further addition of nitrogen and small quantities of sulphur and phosphorus to produce protoplasm, the "physical basis of life." Again, it would have to be foreseen that for the ultimate appearance of the highest animal forms, including Man, it would be necessary that at a very early stage animals and plants should become differentiated from one another, plants having the function assigned to them of storing up the energy which was afterwards to be passed on to animals, thereby enabling the latter to perform all their manifold and ever-increasing activities.

These are just a few of the things which would have to have been taken into account by any merely Finite Intelligence whom we might suppose to have been the original cause of Life on our planet, and of all its marvellous subsequent developments. I shall endeavour to show, however, in the chapters still to follow, how impossible it is for the mind to rest in any such hypothesis.

There is another important matter on which something remains to be said. Whatever may be the precise nature of the Intelligence to whom the course of Evolution is to be referred, in what manner shall we conceive of His relation to those innumerable psyches whose existence we were led to assume (Chapter XXI) in order to explain individual development? As already stated, we can scarcely imagine them to be conscious entities, unless perhaps in a very dim and shadowy way. At the same time, according to the theory advanced in Chapters XXI-XXIII, they have been stocked—and especially in the case of all the higher organisms—with a vast accumulation of memories, which must be arranged, so we thought, in some sort of a lineal

series, for them to give rise to that orderly succession of stages, through which every individual passes in the course of its development.

But of what past happenings are these memories the representation? They must be the representation of those innumerable progressive changes, those variations, which down the long geological ages were gradually wrought in the germ-cells of more or less remote ancestors. And inasmuch as in this chapter we have been led to attribute at least all the most important of these variations to the continually exerted activity of some Superior and fully conscious Mind, His relation to the individual psyches must be such, that our best and simplest way of regarding it is to believe that these individual psyches are all somehow comprehended in Him, form parts, so to speak, of His very Being. His is the one all-embracing Spirit in whom all other lesser spirits on the earth exist, whatever may be the degree of consciousness to which they have attained, or however great in many instances may be their lack of it.

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CHAPTER XXVII

THE ASTRONOMICAL BACKGROUND

IF the discussions continued through most of the preceding chapters have led to any assured result, it is evident that an important stage has been reached in the general argument of this book. It may be as well, therefore, before proceeding to our next subject, to recall briefly the several steps by which we have come to see how impossible it is to interpret Life along purely mechanistic lines.

First, there are the anatomical and physiological facts, the remarkable purposiveness of which, together with their extreme complexity, force home upon us the conviction that in some form or another Intelligence must have been at work.¹

Secondly, there are the embryological facts which stand in still greater need of explanation. They not only afford numberless other most striking examples of purposiveness, but in the case of multicellular organisms present us with a problem which no theory hitherto put forward, and taking cognisance only of the ordinary physical and chemical forces, has been able to solve. Neither Darwin's gemmules, nor Weismann's ids, nor any of the other more recent hypotheses suggested by the Mendelian laws and by the peculiar behaviour of chromosomes, has succeeded in clearing up the mystery, as to how the minute and comparatively simple germ-cell manages to develop into the highly organised adult individual. Consequently, to account for this we were led to postulate in the case of every animal and plant, whatever might be its position in the scale of life, the existence of a certain invisible entity of a mental

¹ Chapters VI to XII.

order which we agreed to call its "psyche."¹ Further, we conceived of the psyche as possessed of some sort of an unconscious memory which during the development of the individual caused it to pass through all, or nearly all, its ancestral stages.²

Thirdly, there are the facts on which the modern Theory of Evolution is based, and which furnish such overwhelming evidence that all animals and plants, which have at any period flourished on the earth, constitute in virtue of their genetic relations to one another one vast, all-embracing System. But this implies the occurrence of an immense number of successive variations which, as every other explanation proves insufficient, can only be ascribed to the action of some single, fully conscious, purposing Intelligence who must have been directing the entire Evolutionary Process from the first.³ This does not preclude, however, the possibility of other minor causes having operated as well.

But to pass on. It is one thing to have reached the conclusion that Life on our little planet can only be explained as the work of some Superior Mind—one immeasurably superior to our own; it is quite another thing to conclude of the Universe as a whole, with its illimitable spaces and its myriads of stars each more or less comparable with our own Sun, that it proceeds from the same Source. The special difficulty with which we are confronted here never occurred, of course, to those who only a few centuries back believed that the earth was the fixed centre of the Universe, and that round it was revolving, and for its sole benefit, the entire host of heaven. Nor should we ourselves have been sensible of the difficulty, if along with the enormous advance which has since been made in every department of biological science, there had been no corresponding advance in Astronomy. Under such circumstances we should naturally have assumed that He who had called life into existence, and through so long and wonderful a process had at last caused Man to arise, had previously called into

¹ That it is truly an entity, not a mere function of the brain, will be more fully discussed in Chapter XXXVI, pp. 536-543.

² Chapters XIV to XXIII.

³ Chapters XXIV to XXVI.

existence the world of inorganic things, that so it might form the necessary stage on which the great drama of Life, and of human life in particular, might be enacted. But in view of all that modern Astronomy has revealed, and especially during the last few decades, as to the colossal scale on which the Universe has been constructed, we may well hesitate before making any such assumption. It would seem desirable, therefore, at this point that we should try to familiarise ourselves with the main facts in connection with this important subject. The following may serve perhaps as a brief description of them.

First, there is the fact now so thoroughly well established that the Earth is after all only one, and that by no means the largest, of a number of other little worlds called planets, which are continually circling about their great central luminary, the Sun. These planets, reckoning from the one nearest to him, form the well-known series—Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus and Neptune. Besides these eight there are more than a thousand very much smaller ones, the so-called asteroids, whose orbits¹ lie between those of Mars and Jupiter. Again, all the larger planets, with the exception of Mercury and Venus, have revolving round them one or more satellites or moons, Saturn, moreover, being accompanied by a remarkable system of rings. In addition to the foregoing, and as constituting part of the Solar System or Sun's family, we have a large number of comets and meteor shoals moving round him in highly elongated orbits.

As to the dimensions of the Solar System, it will be enough to state that the diameter of the orbit of Neptune, the farthest off of the planets, is 5600 millions of miles—a distance which it would take light, travelling at its known speed of 186,000 miles a second, 8 hours and 23 minutes to accomplish. The Sun himself is not only larger, but enormously larger, than all his attendant little worlds put together, so that if by some means they could be suddenly merged in him, they would not make any appreciable difference to his apparent

¹ An orbit is the path described by a planet in its journey round the Sun.

size. He exceeds the Earth in volume by more than a million times, and his mass (or weight) ¹ is 750 times greater than that of all the planets put together.² Again, whereas the Sun is an intensely hot incandescent body with a surface temperature of about 6000° C., and is perpetually radiating immense quantities of light and heat in every direction, they are all, comparatively speaking, cold and dark little bodies shining only by his reflected beams. Lastly, it has been shown that the Sun is journeying through space, and at the same time carrying the entire Solar System with him, at a speed of about 12½ miles a second, his course at present being directed to a point not far from Vega, the beautiful and very brilliant star in the constellation of the Lyre.

But the Solar System, vast as are its dimensions, dwindles almost into nothingness when compared with the far vaster System of the Stars. And, first, as to their number, which is simply prodigious. Although not more than about 6000 are visible by the naked eye, according to a recent estimate by Seares and Rhijn there are close upon 1700 millions of them, capable, through the great telescope on Mount Wilson, of impressing their images on the photographic plate. Further, there is reason to believe that if only we possessed an object glass or mirror of sufficient aperture, this number would be increased to somewhere between 30,000 and 40,000 millions.³ And yet amid all this profusion of worlds we have to remember that our Sun is but a single star.

The distances separating the stars from one another and from the Earth are equally astounding. Even the nearest of them, Proxima, in the constellation of the Centaur, is no less than 25 billions of miles away ⁴—a distance equal to 4400 times the diameter of the Solar System. This means that light, coming to us from Proxima, takes about 4 years on its journey, although travelling at the terrific speed mentioned above. From Sirius, the great Dog Star, and the leader of the host of heaven, it takes 9 years ; from Arcturus

¹ There is scientifically a distinction between these two terms, but in a work like this it may be ignored.

² 1949 quadrillions of tons.

³ Peter Doig, *Stellar Astronomy*, p. 28.

⁴ That is, 25,000,000,000,000 miles.

and Vega, 30 years; from Capella, 54 years; while from Rigel, the splendid jewel in the left foot of Orion, it takes nearly 500 years.¹ Consequently, the light by which we now see Rigel must have started off on its long journey in the days of Joan of Arc. The truth is, we do not see any of the stars as they really are at the present time; we only see them as they were once, and each of them at a more or less remote epoch in the past. Again, as affording some faint idea of the tremendous distances separating them from one another and from us, among their countless multitudes there are only six, including Sirius and Proxima, already mentioned, which, so far as is known, are within 60 billion miles of us. All the rest lie out in the well-nigh immeasurable depths beyond.

Even to the most casual observer the stars differ greatly from one another in their *apparent* brightness—in what astronomers usually describe as their “magnitude.”² In estimating, however, their *real* brightness or “luminosity”—that is, the amount of light which they are actually pouring forth into space—we have to take into consideration the very different distances at which they are placed. When this is done, the luminosity of most of them is found to exceed greatly that of the Sun. Thus if we represent the latter by unity, we shall have to represent the luminosities of the following twelve well-known stars, viz. Procyon, Altair, Sirius, Vega, Aldebaran, Arcturus, Capella, Betelgeuse, Antares, Deneb, Rigel and Canopus, by the numbers 6, 9, 26, 48, 92, 105, 170, 1200, 3300, 10,000, 17,000 and 75,000 respectively.³ If Sirius, with a luminosity of only 26, appears as the brightest of them all, this is simply because he is comparatively so near to us—only about 51 billions of miles away. There are other stars, it should be said, whose luminosities are very much less than that of the Sun.

It was formerly the belief that the stars were fixed in space, but it has been known now for a very long time that,

¹ G. E. Hale, *The Depths of the Universe*, pp. 16-18.

² This term has nothing whatever to do with their actual size.

³ There is a star in the Southern Hemisphere known as S. Doradus, the luminosity of which is stated to be 300,000.—Harlow Shapley, *Starlight*, p. 20.

like the Sun, they are all in more or less rapid motion. Their average speed is about 20 miles a second, but there are some which are travelling far more swiftly. Thus the

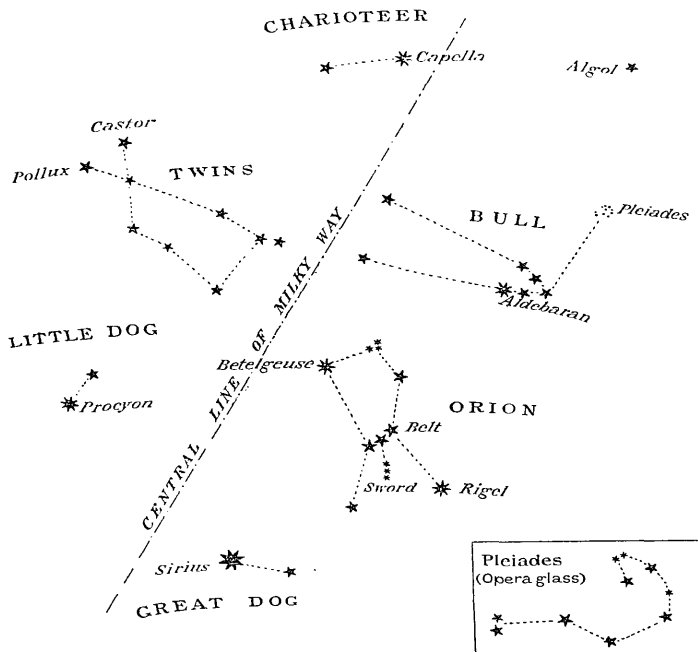


FIG. 52.—WINTER STARS, LOOKING SOUTH.

Most of the stars are mentioned in the text. Castor is a well-known Binary. Sirius and Procyon have minute attendants. Capella is a close Binary. Algor is the famous Demon star (a variable). The great Nebula in Orion surrounds the middle star in the sword.

star, "Lalande 1966," has a speed ten times greater than the average, while the variable star, "N.Z." in Cepheus,¹ is rushing along through space at the appalling velocity of 625 miles per second. Yet so remote from us are most of the stars, that often several years have to elapse before

¹ H. Dingle, *Modern Astrophysics*, p. 92.

any appreciable change in their apparent positions can be detected.

Practically nothing was known about the real nature of the stars till near the beginning of last century. It was then shown not only that a great number of them were doubles, but that in many cases their components were physically connected, inasmuch as they were revolving round one another in elliptical orbits in conformity with the law of gravitation—that same law which governs and explains all the movements within the Solar System. But this meant that although they might still appear through the most powerful telescopes as mere points of light, they were nevertheless ponderable bodies—possessed, that is, of mass or weight. In many cases, incredible as it may seem, their masses have actually been calculated, and it has been shown among other things that the most massive of them are not more than about a hundred times heavier than the lightest. This last accords well with theory, for it has been proved mathematically that unless a star keeps within these bounds, either it will develop forces which will lead on to its disruption, or it will not attain a temperature high enough for it to become incandescent, and hence to shine.¹ By means of the spectroscope, that great modern engine of astronomical research, we know now that a far larger number of the stars are doubles than had previously been supposed—some say about a third of them. Their periods of revolution vary from a few hours up to several centuries, and their components are placed at all sorts of distances apart.² The theory is, that most of them, if not all, were originally single stars, but that owing to their very swift axial rotations they subsequently split into two. Moreover, the components in each case are supposed to be gradually drawing further asunder as the result of their tidal action on each other. In fact, there is a star not far from Vega,

¹ A. S. Eddington, article in *Nature*, May 1923; also his *Internal Constitution of the Stars*, p. 151.

² Castor, for example, in the constellation of the Twins, is a well-known double, its components revolving round each other in 347 years. Capella is another, a very close double, and Sirius and Procyon are each accompanied by a minute attendant.

called Sheliak, which is thought to consist of two enormous pear-shaped bodies which have only recently separated, or, it may be, are still just in contact with each other at their more pointed ends. In many instances, too, the process of division has been gone through more than once, and has led to the formation of triple, quadruple and multiple stars.

As to their inner constitution, it is believed to-day that the stars are nothing else than huge masses of incandescent gas of spherical shape, held together by the gravitation of their ultimate particles.¹ They are composed, so the spectro-scope informs us, of practically the same chemical elements as those with which we are familiar on the Earth. It is a remarkable fact that one of these elements, viz. helium, was not known on the Earth until many years after its presence had been detected by Sir Norman Lockyer both in the Sun and in several of the stars in Orion.

The stars differ from one another very considerably in their surface temperatures, which range from about 2500° C. in the red and copper-coloured ones like Betelgeuse and Antares, to between $20,000^{\circ}$ C. and $30,000^{\circ}$ C. in the bluish-white ones like Spica and Rigel. Their internal temperatures, however, vastly exceed these limits, reaching up very often, according to Professor Eddington, to something like $40,000,000^{\circ}$ C.² How it has been possible for these excessively high temperatures to be maintained during the countless millions of years of a star's existence has been one of the most puzzling problems in Astronomy. Various theories have been put forth on the subject at different times. The most recent one is that the necessary heat has been, and is still being, generated by an actual destruction of matter going on continually in the star's deep interior. For instance, to enable the Sun on this theory to maintain its present temperature, it has been estimated that some four million tons of its substance must be destroyed in it every second.³ But this is not such a serious amount as might be imagined, for the mass of the Sun is so great that it will

¹ It has recently been suggested that the central portions of many of the stars are probably liquid.—J. H. Jeans, *Astronomy and Cosmogony*, pp. 104, 160.

² A. S. Eddington, *Stars and Atoms*, p. 14.

³ J. H. Jeans, "The Birth of Worlds," in Harmsworth's *Universal History*.

take some sixteen million million years before the work of destruction will be complete, granting, that is, that the process should be continued at the same rate.

Much has latterly been made out as to the successive stages through which most of the stars pass ¹ in the course of their evolution. To begin with, they are exceedingly tenuous bodies, but of immense proportions. According to measurements made in America with a comparatively modern instrument, viz. the interferometer, Arcturus, for example, is said to be 21 millions of miles in diameter, while the diameter of Antares, the brilliant red star in the constellation of the Scorpion, has been put down at 400 millions, or 462 times greater than that of the Sun.² As evolution proceeds the stars slowly contract, owing to the force of gravitation. Simultaneously their temperatures rise, and the light which they emit changes from red to orange, and through various tints of yellow to pure white. At least this is true of the majority of stars. After this a state of things supervenes when, though they still go on contracting, their temperatures fall and their light passes through the same colour changes as before, but in the reverse order. Finally, they become quite dark and cold, the entire process having occupied incalculable æons of time. The larger, the enormously distended stars in which the temperature is still rising, are known as the Giants, whereas the smaller and much denser ones in which it is falling are known as the Dwarfs. Our Sun is one of the Dwarfs.

Hitherto we have been considering the stars as so many isolated bodies differing among themselves in size, weight, colour, temperature, luminosity, etc.; we have now to consider them in their relations to one another, and more particularly in the manner of their distribution throughout space. The first point perhaps to be noted is that even to the naked eye they are by no means scattered in equal numbers about the heavens. They have a decided tendency

¹ Those belonging to what is known as "the main sequence."

² G. E. Hale, *The New Heavens*, p. 57. The Sun's diameter is about 865,000 miles, or 109 times that of the Earth.

towards clustering, as is well seen in the case of the Pleiades in the Bull, the Beehive in the Crab, and the very beautiful double cluster in the Sword Handle of Perseus.¹ But far more imposing than any of these is that great congeries of stars which has been known from time immemorial as the Galaxy or Milky Way, and which on a fine moonless night, and especially during the autumn season, may be observed stretching like an immense luminous arch over our heads. Only one-half of it, however, can be seen at a given time. The other half is always hidden beneath the horizon; but could we view it as a whole, it would present the appearance of a vast irregularly shaped, ringlike structure encircling the whole heavens. Not all its parts are equally bright, and over about a third of its extent it shows a division into two distinct branches. Also, we may notice here and there what look like dark rifts and holes in it, one of which, not far from the Southern Cross, has been named the Coal Sack. They are probably not holes at all, but are due to certain obscuring clouds to which I shall refer presently.

To take in the full splendour of the Milky Way we must look at it through some powerful telescope, capable of resolving its mysterious patches of light into myriads of apparently very minute stars. They are, of course, not really minute; it is simply their tremendous distances which may incline us at first to think so. How far, then, are they actually off, or rather how far off are the farthest of them? It is a question to which an approximate answer has only quite recently been given. But to go back for a moment into the past, it was the great Sir William Herschel who rather more than a century ago first broached the theory that all the stars, whether far away or comparatively near, formed but a single System, and were comprised within a certain definite space roughly resembling in shape a biconvex lens. Moreover, he supposed the Sun with its retinue of planets to be situated somewhere near the centre of this System, so that in looking out in the direction of its circumference he considered that he was looking out in the direction

¹ These are all well worth looking at through binoculars. See H. Dingle, *Astrophysics*, pp. 346, 347.

in which the stars would naturally appear to be most closely packed together. Among the stars in that direction there would necessarily be those which were farthest off. It was these, of course, which produced the appearance of the Milky Way.

Now the theory held to-day on this subject is substantially the same as Sir William Herschel's, except that in the hands of Dr Harlow Shapley and others it has undergone three rather important modifications. And, first, the space containing the stars is believed to be much more flattened out than was originally supposed—to be disc-shaped rather than lenticular. The Solar System, too, is no longer supposed to be centrally placed in it, but to be two or three times nearer to the Milky Way in the direction of the constellation of the Twins, than in the opposite direction of the Archer. It is situated also slightly to the north of the Galactic Plane. Again, owing to some of the quite new methods now employed in the measurement of celestial distances, it has been shown that the dimensions of this disc-like space enormously exceed anything hitherto dimly dreamed of. They are such that light, travelling with its known velocity of 186,000 miles a second, would take about 300,000 years to cross the immense interval corresponding to its diameter, and about 10,000 years to traverse its thickness.¹ Contrast these figures with the 500 years which light takes in its journey to us from Rigel. It must not be inferred, however, from what has been said above that the Galaxy comes anywhere to an abrupt end. As we approached its confines, we should probably find that the stars were gradually thinning out.

Such, then, is the colossal scale on which, as it is now believed, the Physical Universe has been constructed, although, as we shall see presently, we have not yet quite got to the end of the story.

The Galaxy—using that term now to include the entire system of things hitherto described—contains not only stars, but those very remarkable objects known as nebulae. They are variously shaped, cloudlike masses of prodigious

¹ Peter Doig, *Stellar Astronomy*, p. 139.

extent scattered about in different regions of the sky, and shining, most of them, with a ghostly, faintly glimmering light. Some of them have been proved by the spectroscope to consist of highly rarefied gases, while others are probably enormous clouds of meteoric matter or dust. Moreover, there are dark nebulae as well as bright ones, and these are often of such thickness as to blot out completely any stars which may happen to be behind them. When projected against the Milky Way, they produce the appearance of those dark holes and rifts in it already mentioned. Elsewhere, as in the case of the nebulous matter surrounding the Pleiades and of the great nebula in Orion,¹ they are apparently lit up and made to glow by the stars in their immediate vicinity. According to one theory, the particles of which the nebulae are composed have been forcibly ejected from certain of the high temperature stars by what is known as "light pressure." It has also been suggested, as perhaps the most probable explanation of the so-called *Novae* or "temporary stars"—like the magnificent one which unexpectedly blazed out in Perseus in 1901—that they are the result of the swift rushing of certain dark bodies, stars possibly which long ago became extinct, through enormous stretches of nebulous matter. It would be the friction thus produced which would cause them to burst out with such extraordinary suddenness.

Among celestial objects, perhaps the most striking of all are those vast agglomerations of stars known as the Globular Clusters, of which between seventy and eighty have now been discovered.² As a typical example I may mention the great cluster in the constellation of Hercules. According to Dr Shapley, its light takes about 36,000 years to reach us, and it is composed of stars 35,000 of which are equal in brightness to the Sun, while at least three of them are a hundred times brighter.³ It is not only, as its name implies, globular in shape, but the stars composing it are increasingly crowded together the nearer they are to its

¹ Through a pair of opera-glasses this nebula can be dimly seen surrounding the middle star in Orion's Sword.

² J. H. Jeans, *Astronomy and Cosmogony*, p. 26.

³ G. E. Hale, *The Depths of the Universe*, p. 34.

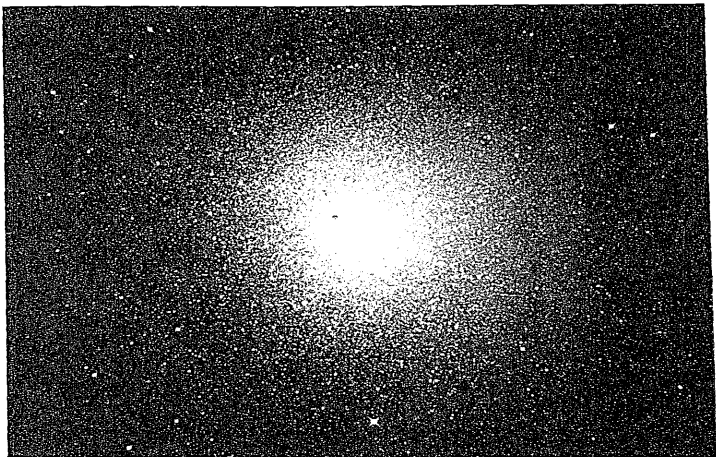


Fig. 53. The Great Star Cluster (M. 13) in *Hercules*.



Fig. 54. A Spiral Nebula.

(Mount Wilson Observatory Photographs).

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Fig. 53. The Great Star Cluster (M. 13) in *Hercules*.



Fig. 54. A Spiral Nebula.

(Mount Wilson Observatory Photographs).



centre. The comparatively small space which it appears to occupy in the sky is entirely due to its immense distance from us, although its actual diameter is said to be five million times greater than that of the Earth's orbit.¹ There is another cluster, not far from Arcturus, said to contain in its central portion 150,000 stars, which are at least four times brighter than the Sun.

There are two very interesting points in connection with these globular clusters. The first is that, strictly speaking, they can scarcely be regarded as true members of the Galactic System, seeing that they are nearly all situated outside its boundaries. At the same time they certainly stand in some sort of relation to it, for they are not, as stellar distances go, so very far removed from it; and, besides, they are distributed in a fairly symmetrical manner with respect to it, some being to the north of it, and about an equal number to the south. Secondly, and as confirming what has just been said, it appears that with but few exceptions they are all travelling towards us, so that probably at some period not indefinitely remote they will become absorbed in the general Galactic System. This, it is supposed, has already occurred in the case of the Pleiades and of several other similar groups. The opinion also has been hazarded, that the entire Galaxy has been largely built up of Globular Clusters drawn in from without in the manner described. They have since, however, become more or less broken up, the individual stars belonging to them having been scattered abroad in various directions, owing to the gravitative forces exerted upon them by the other stars into whose neighbourhood they have now come.

But the Physical Universe, regarded as a whole, extends out into regions of space far beyond any of which we have hitherto spoken. For it is practically certain now that the so-called *Spiral Nebulae* are systems entirely external to the great Galactic System to which our Sun belongs. They have sometimes been described as *Island Universes*, but the term is obviously inappropriate, as there can be but one Universe, viz. that which embraces all. It has recently

¹ H. Spencer Jones, *General Astronomy*, p. 299.

been estimated that about two millions of these wonderful objects should be visible through the great 100-inch telescope on Mount Wilson. According to Dr Jeans, it is possible to arrange them in a sort of serial order, representing the various stages through which they pass in the course of their evolution.¹ At first they are spherical in shape, but as a result of their rotational movements they bulge out equatorially and become ellipsoidal, then lenticular, and by and by flat and discoidal. Next, at two opposite points they begin to throw out a couple of long, spirally curved arms, which in course of time become their most characteristic feature. This, of course, is the reason why they have been called Spiral Nebulæ, although the name strictly applies only to those which have attained their full development. In speaking of them as *Nebulæ*, we must be careful not to confuse them with the nebulæ previously referred to, with which indeed they have hardly anything in common. For one thing they are enormously bigger; hence it would be better perhaps to call them simply *Spirals*. They are set at every sort of angle to our line of sight: some of them we see full-face, as it were; others we see only edgewise; while the rest are variously tilted with respect to us.

Perhaps the most famous of them all is the great Spiral in the constellation of Andromeda. Its light is said to take nearly a million years to come to us, which means a distance about three times greater than the diameter of the Galactic System.² It can just be glimpsed by the naked eye, and is of all objects visible by the naked eye the one which is farthest off. Its diameter is stated to be about a tenth of that of the Galactic System, and it is rapidly approaching us at the rate of 200 miles per second. Its central portion, known as the nucleus, together with its enormously extended arms, has been shown to be rotating; but ten thousand centuries, it is said, will have to go by before it has completed a single revolution. As in the case of most of the other fully formed Spirals, its arms are seen to

¹ J. H. Jeans, "The Birth of Worlds," in Harmsworth's *Universal History*, pp. 56-59.

² From certain of the Spirals light is said to take 140 million years to come.—J. H. Jeans, *Astronomy and Cosmogony*, p. 12.

be breaking up into separate masses, which according to Dr Jeans will ultimately become stars, numbering in all about a thousand million. In fact he regards the Spirals generally as those special places in the Universe where stars are being born. It has been conjectured also by some that what we call the Galactic System is itself nothing else than a gigantic Spiral, which now with the exception of a certain residual amount of nebulous matter, similar to that surrounding the Pleiades, has resolved itself entirely into stars.

In the above description I may seem to have entered into an almost unnecessary amount of detail, but it is only because I felt how essential it was that we should thoroughly realise the nature of the problem before us. In the earlier portion of this work we have been concerned almost exclusively with the phenomena of Life on our own little world, and from our study of it we have endeavoured to reach certain important conclusions. But clearly no ultimate conclusion, such as we are in search of, can be drawn, till we have considered the full bearing upon our general problem of those stupendous facts to which we have given attention in the present chapter. The Earth on which we live, and on which organic evolution has run its wonderful course, appears to shrink into utter insignificance, whether we reflect on the well-nigh inconceivable vastness of the Sidereal System as regards both Space and Time, or we compare our little planet with any one of those countless millions of distant orbs, those mighty suns, which nightly sparkle out in the heavens. Although, then, we may quite legitimately have inferred that Life as we know it here is wholly inexplicable apart from the constant guidance and activity of some unseen Master Mind, we should be going far beyond the evidence hitherto taken into account, if without further consideration we identified it with that Supreme Mind—if Supreme Mind there be—from whom it has been thought that the entire Universe proceeds. As to the extent to which it may be possible to deal successfully with this highly important question, I shall try to show in the two following chapters.

CHAPTER XXVIII

POSSIBILITIES OF LIFE ELSEWHERE

IN endeavouring to grapple with the problem with which we are now faced, let us suppose that by some means we could positively be assured that scattered about in the vast fields of space there were other worlds beside our own in which Life had come to the birth, and had undergone a process of evolution similar to that which has occurred on the Earth. Would not that at once put a different aspect on the whole subject? For it would mean surely that somehow pervading the entire Universe there was a Power which, whenever and wherever the conditions were favourable, tended to produce Life, and along with it Mind, which, as we have seen, is to be regarded not merely as its invariable concomitant but as its deepest essence.¹ But a Power capable of producing Mind must itself be of the nature of Mind.² Hence Mind would have to be conceived of as everywhere present in the Universe, and from this it might not unreasonably be concluded that it had given origin, not only to living beings, but to the whole realm of the inorganic as well. Thus along a comparatively easy route we should be brought well within sight of monotheism.

Unfortunately for this line of argument there is no direct evidence to show that any other world beside the Earth is the actual abode of Life, with the possible exception of the planet Mars, to which I shall have to return presently. That matters should stand thus need not, however, occasion the least surprise, when we think of the enormous distances which separate us from the nearest even of the heavenly

¹ See Chapter XXI.

² This follows from all that has been said previously.

bodies, and of the impossibility, therefore, of our perceiving any clear indications of Life upon them, although equipped with the most powerful modern telescopes.

At this point there is a preliminary question of considerable importance to be discussed. If Life exists in other worlds and is essentially of the same nature as it is on the Earth, then this could not have come about unless in each instance the immediate environment had furnished it with all the needful conditions. Thus a moderate and yet a sufficiently high temperature is obviously a *sine quâ non*. Life cannot possibly be present on bodies which, like the sun and the stars, are still in a state of incandescence; neither can it be present where the temperature has fallen, say, to a hundred degrees below zero. At the same time the conditions need not everywhere be exactly alike. We may gather this from the extraordinary manner in which here on our own little world Life has adapted itself to surroundings of the most varied kind. The sea, the dry land and the air, all bear witness to its universal presence. It has penetrated into the deepest ocean abysses where no light ever comes,¹ and it has climbed up the mountain sides to elevations many thousands of feet above the valleys below. In swamps reeking with moisture and in arid deserts it has alike been able to secure a home, and if in tropical lands it has run riot under the burning rays of the sun, it has gained a foothold, though a precarious one, in the regions of ice and snow which encircle the poles.

Now this marvellous power of adaptation which Life has displayed, and which has been developed here under purely terrestrial conditions, may well under conditions prevailing elsewhere have led to the production of forms differing widely both in outward appearance, and in many other respects, from those with which we happen to be familiar. Yet when every allowance for this has been made, it is still true that, if Life in other worlds is at all to correspond with what we have found it to be on the Earth, it must be subject to certain limitations of a more or less stringent character. What these limitations are we have

¹ See Chapter XII, p. 149.

now to consider, as also the probability of their being complied with elsewhere.

1. And first, all those chemical elements must be present which are necessary for the construction of protoplasm; the "physical basis of life." Protoplasm, as we have seen, is the essentially living substance in every animal and vegetable cell, and apart from it not one of the various physiological functions can be carried on. In Chapter III I have given a list of the elements in question. They are fourteen in all, viz. oxygen, hydrogen, nitrogen, carbon—the four principal ones—and chlorine, sulphur, phosphorus, iron, calcium, magnesium, sodium, potassium, fluorine and silicon. Of these the last two may be omitted as unessential, seeing that they only occur among particular groups of organisms—silicon, for example, in the leaves of grasses, in certain sponges, and in the shells and other skeletal structures of many of the invertebrates.

Now a century ago it would have been thought utterly impossible for anybody to find out of what substances the heavenly bodies are composed. This miracle, however, has been accomplished, as already explained, by means of the spectroscope, and it has been shown that at least twelve out of the above-named fourteen elements exist in the Sun and in the Stars. As to the remaining two, namely, fluorine and phosphorus, there are special reasons why the spectroscope should fail to detect them. We know, however, on quite other evidence that at least phosphorus exists in meteorites. Further, there is good reason to believe that *all* the chemical elements—of which ninety out of the possible ninety-two have now been discovered on the Earth—exist elsewhere among the heavenly bodies. Hence, in so far as this first condition is concerned, there is nothing to hinder Life from appearing in almost any of the many millions of worlds scattered throughout space.

2. Another necessary condition is the presence of water, that most important perhaps of all chemical compounds. Not only does considerably more than half the substance of protoplasm consist of it, but it is absolutely indispensable for the carrying on inside the body of all those many pro-

cesses on which Life depends. For example, if there were no water, clearly there could be neither sap in plants, nor blood in animals, for the conveyance of the necessary nutrient materials to the various organs and tissues. Again, nearly all the bodily functions are ultimately resolvable into changes of a chemical nature—changes which can only take place when water is present. Moreover, it appears that all the earliest forms of Life originated in the sea—that is, in the midst of a watery environment—and that only gradually, by successive invasions of the land and the air, did they afterwards become adapted to different surroundings.

As to the existence of water elsewhere than upon the Earth there can be but little doubt. Inasmuch as oxygen and hydrogen, its two components, have been shown by the spectroscope to be universally present—that is, in all celestial bodies which are incandescent—we may safely infer that water will have been formed in nearly every world which has sufficiently cooled down for the oxygen and the hydrogen in it to unite. We know from experiment that at all ordinary temperatures these two gases will do so on the slightest provocation, and often with considerable violence.

Evidence to the same effect, but of an independent kind, is furnished by the two great planets, Jupiter and Saturn, the atmospheres of which appear through the telescope to be heavily laden with clouds, and these, it is difficult to believe, can be composed of anything else but water particles. Again, we have the planet Mars, the polar regions of which are covered at times with what are evidently ice-caps, for they are of a glistening white, and can be observed through our telescopes melting and subsequently forming again according to the progress of the Martian seasons.¹

3. It is further necessary that there should be an atmosphere containing both free oxygen (O_2) and carbon dioxide (CO_2).

Free oxygen must be present, because without it respiration could not be carried on, and respiration is apparently

¹ Percival Lowell, *Mars and its Canals*, pp. 32–53.

the only means by which living organisms can extract for their own benefit the energy stored up in those highly complex compounds, of which a brief account was given in Chapter III. And energy, as we saw in Chapters IV, VII and IX, is absolutely essential for the performance of all the vital functions.

Carbon dioxide must also be present in the atmosphere, as it is the only source from which plants—and through them animals—can obtain their carbon, that element which of all others is most necessary for the building up of the complex compounds just referred to. Their complexity, or rather the complexity of their molecules, is due to that remarkable property possessed by carbon atoms of linking themselves together in long chains and peculiarly shaped ringlike structures, and of forming in this way kind of nuclei to which the atoms of other elements can be attached. Sometimes, as the result of this property, hundreds and even thousands of atoms will enter into the composition of what is apparently a single molecule, and it is chiefly molecules of this description which in their turn enter into the composition of protoplasm. From this we learn how important an element carbon is in relation to Life.

That both oxygen and carbon exist in incandescent bodies like the sun and the stars is unquestionably the case. The only doubt is, as to whether oxygen in its *free or uncombined state* is always present in those bodies in which the temperature has fallen low enough for Life to be possible. The fact is, that at temperatures at all approximating that of the Earth, the affinity of oxygen for the other elements becomes so great that it will combine with the utmost avidity with nearly all of them. Hence in many of the heavenly bodies this may have occurred to such an extent, as that none of their original supply of oxygen may remain over in the uncombined state, so as to be available for respiratory purposes. We are bound to admit the possibility of this, and especially in view of the known fact, that immense quantities of oxygen are now locked up in combination with other elements to form the minerals which compose the Earth's crust. For instance, in granite, which is composed of the

three minerals, felspar, mica and quartz, the proportion by weight of oxygen in them is about 50 per cent., and the same remark applies to many of the sedimentary rocks, such as the sandstones and the limestones.

On the other hand, it may fairly be urged that the enormous preponderance of oxygen in the Earth's crust would naturally lead us to expect a similar preponderance of it throughout the Universe generally. Granting that this is the case, it is surely extremely unlikely that ours is the only world at a moderate temperature, in the atmosphere of which free oxygen exists. For although in several worlds, more or less resembling the Earth, the deficiency of it may originally have been such, as that afterwards none remained over for respiratory purposes, yet in others the excess of it may have been such as to have produced a result just the opposite. Anyhow if, as is thought, the Universe contains at least as many dark bodies as bright ones—and let us remember that of the latter there are said to be thousands of millions—then amid that vast multitude there must almost certainly be some in the atmospheres of which oxygen is present in the free state.

A doubt similar to that which applies to oxygen scarcely applies to carbon dioxide. It is true, that on the Earth immense quantities of it now exist in combination with lime (CaO) and magnesia (MgO)—for example, 44 per cent. of it in such rocks as chalk and mountain limestone. But this cannot always have been the case, as most of the carbon dioxide now present in this solidified condition must at one time have been got out of the atmosphere, which was much more heavily laden with it in early geological times than it is to-day. Again, the carbon contained in peat, coal and the various mineral oils must also have been got out of the atmosphere by the agency of plants.

There is another important point in connection with this subject which must not be forgotten. It is that for any world to possess an atmosphere at all, the gravitative force at its surface must be sufficient to prevent its gases from flying off into space. Now the strength of this force depends on the mass or weight of the body exerting it. Hence

it is extremely unlikely that Life can exist on any of the smaller and, therefore, lighter bodies belonging to the Solar System, such as the satellites and the asteroids. The eight larger planets are consequently the only worlds on which there can be any prospect of Life being found. This does not, of course, exclude the possibility of its existing elsewhere in the Universe regarded as a whole.

4. Further, that a world may be an abode of life it is, as we have seen, a necessary condition that its temperature should be neither too high nor too low. If too high, any water it may possess will be converted into steam; if too low, it will be converted into ice, under neither of which circumstances could life be maintained for long. Hence not only must all the incandescent bodies in the Universe—with surface temperatures running up from 2500° C. to $30,000^{\circ}$ C.—be uninhabitable, but the same must be true of numberless others which, although not hot enough to emit light, are far too hot for life to be possible on them. Again, at the opposite extreme, seeing that the temperature of space is said to be nearly 273° C. below zero, there must be a third class of bodies which have so far cooled down as to render them equally unfit.

There is a further point to be considered. A heavenly body may obtain its heat from one or other of two sources, and sometimes perhaps from both. It may obtain it from its own internal store, as is possibly done in part by the two great planets, Jupiter and Saturn; or it may obtain it from some external body which, like the Sun, is still in a state of incandescence. Now in the latter case the amount of heat actually received will depend not only on the temperature of the external body, but on its greater or less distance off. Thus within the Solar System the planet Mercury, which is only 36 millions of miles from the Sun, as against our 93 millions, must receive nearly seven times as much heat as the Earth does—that is, if we compare together equal areas of their surfaces. This makes it somewhat doubtful as to whether life can exist on Mercury, unless it be in the vicinity of its poles, as was once suggested by the late R. A. Proctor. On the other hand, Uranus and Neptune, the two outermost

planets, are so far away from the Sun that the amounts of heat received by them are respectively only about $\frac{1}{3600}$ th and $\frac{1}{9000}$ th of what is received by the Earth. This would seem at once to rule out the possibility of Life being found upon them.

We gather, then, from this and from the other conditions previously discussed, that the only bodies in the Solar System besides our own, on which at present there can be much chance of life, are the planets Venus, Mars, Jupiter and Saturn, and even on the last two we might have to suppose that the larger portion of their heat is supplied by themselves. Of course æons ago, when the Sun was far hotter than it is at present, it may be that Life arose and went through a course of evolution upon Uranus and Neptune, just as the same may happen at some distant date on Mercury, when the Sun shall have sufficiently cooled down.

5. There is apparently another condition on the presence of which Life depends. There must be an adequate degree of illumination. As was explained in Chapter IV, plants directly, and animals indirectly, get all the energy they need for the due discharge of their various activities out of the light daily reaching the Earth from the Sun. If, now, we combine this with what was said in the last section, we shall see that, while every world in which Life is to appear must be at a temperature far below incandescence, it must be in the neighbourhood of some other world like the Sun which is incandescent, and is capable, therefore, of supplying it with the light required. Hence such an arrangement as actually prevails in the Solar System would seem to be just the one most favourable to Life, viz. an intensely hot central body with a number of darker and very much smaller bodies revolving round it.

Light is necessary for another reason, at least in so far as animals are concerned, for on account of the comparative scarcity of their food they are compelled to go in search of it (see again Chapter IV). This, however, they could not do, unless to guide them they were provided with eyes. But eyes would be useless without light.

These, then, are the conditions which must be fulfilled if

Life, such as we know it, is to exist elsewhere. We have next to inquire as to the real likelihood of its existing, first of all, within the somewhat restricted limits of the Solar System, and secondly, throughout the Universe generally.

As to the Solar System, Life must be limited, as we have seen, to the four major planets, Venus, Mars, Jupiter and Saturn, with the doubtful inclusion of the last two, and with the possible inclusion of the planet Mercury. Unfortunately, however, each of these five, with the single exception of Mars, is surrounded by so densely laden an atmosphere that it is impossible to catch even a glimpse of its actual surface. Mars, therefore, is the only planet on which there is the remotest chance of our discovering any signs of life; but here again it is very difficult to speak with any degree of certitude. The late Percival Lowell, director of the Flagstaff Observatory in Arizona, was the author of two highly interesting volumes entitled *Mars and its Canals* and *Mars as the Abode of Life*, in which he sought to prove not only the existence of life on that planet, but of intelligent beings as well. He called attention more especially to certain very striking peculiarities which, according to his observations, characterise the so-called Martian "canals"—as, for example, their enormous length, their straightness, their narrowness, their parallelism to one another, and the remarkable manner in which they radiate like the spokes of a wheel from certain spots described by him as *Oases*, often, too, connecting up these spots with others of a geographical, or rather an areographical, importance. These peculiarities, he contended, were so artificial in their appearance, as at once to suggest the idea that they were somehow the work of intelligent beings like ourselves. His theory, as set forth in the two volumes just referred to, is that, owing to the serious loss of water upon Mars and the consequent great extension of its deserts, the inhabitants there have been driven to obtain their water from the periodical melting of the snow and ice about its poles. In order to convey this water to certain ancient centres of civilisation—the aforesaid oases, many of which are now completely surrounded by desert—the Martians have been obliged to

construct this elaborate system of canals, although what we, stationed on the Earth, really perceive are not the canals themselves, but the adjoining strips of fertile land irrigated by them. Lowell also says that, as the result of the melting of the polar snows, he has observed a periodical "flushing of the canals," which, according to the state of the Martian seasons, travels slowly down first from one pole and then from the other in the direction of the planet's equator. This appearance he ascribes to the springing up of fresh vegetation on both sides of the canals in consequence of the arrival of the waters. Moreover, he endeavours to prove that the grey-green areas on the surface of Mars, which present so marked a contrast to its more extensive tawny areas or deserts, are really covered with vegetation, and as bearing this out he asserts that these areas undergo certain changes of colour corresponding to those which occur on the Earth with the coming of Spring and, later on in the year, with the fading and falling of the leaf. Of course, if these last observations of his could be confirmed, it would at least prove the existence of vegetable life upon Mars, and hence the possible existence of animal life as well. Such a conclusion, moreover, would have been reached in complete independence of whatever view may be taken of the "canals." Lowell's speculations, however, in reference to the whole subject have not met with much acceptance on the part of astronomers on this side of the Atlantic. Nor is it easy to see how the question at issue is likely to be settled, unless some day—for wonders will never cease!—we shall be able to communicate with the Martians either telepathically or by means of wireless. It must be remembered, too, in this connection, that Mars never comes nearer to the Earth than 35 millions of miles, and that this only happens once in every fifteen years.

Turning to the far vaster Sidereal System, we have next to ask,—What is the probability that, if not on the stars themselves, yet on some of the comparatively dark little worlds forming their planetary systems, the conditions necessary to life may be found? To this we are naturally inclined to reply that, in view of the enormous number of

the stars, the probability must surely be very great. Nor can it be urged as a valid objection to this that at present we have no direct proof that any such planetary systems exist, seeing that such proof may well be lacking owing to the immense distances from us at which the stars are placed. Our own planets, that is, those which revolve round the Sun, are sufficiently near for us to see them, and to make out many of their details, but as they only shine by the Sun's reflected light they would, if removed to the distance of the nearest star, become quite invisible even through our biggest telescopes, and would not leave the slightest impression on the most sensitive photographic plate. Jupiter, for example, the largest and most brilliant of the planets, would at any of the stellar distances look several millions of times fainter than either of the two stars in the Great Bear known as the "Pointers." Hence with the instrumental means at present at our disposal it is in vain to expect that any direct proof of the existence of planetary systems other than our own will be forthcoming, strongly as we may be disposed to entertain the belief. But as bearing on this subject there are one or two further points to be considered.

According to Laplace, the famous French astronomer who died about a century ago, the Sun, or rather the nebula out of which he supposed it to have been evolved, originally extended considerably beyond the limits of its present most distant attendant. As it contracted it threw off, in consequence of its rapid rotation, a succession of rings which gradually gathered themselves up into the planets, these in their turn by a similar process giving rise to their respective satellites. Now although the Solar System has almost certainly been formed out of materials which, to begin with, were part of the Sun's own substance, Laplace's hypothesis, as he originally formulated it, has been subjected to a considerable amount of criticism. Thus stars—that is, suns—do not as they contract throw off rings in the manner he imagined, but rather, if they are rotating fast enough, divide into two, thereby giving rise to binary systems. Again, the comparatively slow speed with which our own

Sun is at present rotating proves that at no epoch in its past history could the centrifugal force generated by it have been sufficient to throw off either rings or any other large masses of material which might afterwards have been gathered up into planets.

Dr Jeans, therefore, has latterly propounded the theory¹ that for the origin of the Solar System we must look to some wholly external cause—external, that is, to the Sun itself; and accordingly he supposes that untold ages ago some other star, rushing along at enormous speed, passed by it at no very great distance off. This caused the Sun to protrude from itself a long tongue-like mass of material, which, reaching far out into space, subsequently broke up into planets and satellites. Now if this theory is correct, the Solar System presents an arrangement which may be almost, if not quite, unique; for it can be mathematically shown that the chance of any such near approach of two stars to one another, as that assumed, is exceedingly small. *Æons* of time may have to elapse before a similar event occurs. On the other hand, Dr Jeans has himself admitted the possibility of one star out of every 100,000 being surrounded by planets, which have originated in the same way as those attendant upon our sun.² At first sight this may seem a very small proportion, but if we divide by 100,000 the total number of stars—viz. 30,000 million, which according to Seares and Rhijn the Galaxy contains—we get for quotient 300,000. On this showing, then, there may be in the Galaxy as many as 300,000 stars with planetary systems similar to our own, and on which, therefore, Life may have gained a footing and begun to evolve.

Let us suppose, however, that nowhere else in the Universe there exists a planetary system which has originated like our own, that does not preclude the possibility of there being other worlds in which the conditions necessary to life may prevail. We have seen that at least a third of the stars, and it may be half, are doubles, and that most of these

¹ Article on "The Origin of the Solar System," by J. H. Jeans, in *Nature*, March 1, 1924.

² See his address on "The Wider Aspects of Cosmogony," delivered before the Royal Society of Arts, March 7, 1928.

are likely to turn out to be binaries. Now if the components of a binary are approximately equal in size, they will naturally cool down at about the same rate, and neither of them will be able to become an abode of life. If, on the other hand, they are unequal, as is often the case, the smaller one will cool down the more rapidly, and will by and by reach a temperature which will permit of life, while the larger one, still incandescent, will be able to supply it with the requisite amount of light. Nor does this exhaust all the possibilities, for according to Arrhenius the number of stars, which have already cooled down and have thus ceased to shine, is probably a hundred times greater than that of the stars which still remain luminous.¹ But if that be so, then why should not multitudes of them in the densely crowded regions of the Milky Way, or far away perhaps in the great Globular Clusters, or in some of the more advanced Spirals, be companions to others which are still in a glowing condition, and are able, therefore, to supply them with the heat and light necessary for life to exist?

But the whole subject needs treatment from a much more fundamental point of view, and to this, therefore, I intend to devote the following chapter.

¹ Arrhenius, *Worlds in the Making*, p. 151.

CHAPTER XXIX

THE ADVENT OF LIFE AND MIND

AN inquisitive lad, in conversation with a much older friend, once asked the question, "How did the Universe begin?" and was no doubt considerably disappointed with the unsatisfactory character of the answer he received. The proper answer, of course, was and is, that the Universe never began, if by the Universe we mean the totality of existence, comprising, that is, all things of a spiritual as well as of a material kind. *Ex nihilo nihil fit*. Out of nothing nothing could ever have come; something, therefore, must necessarily have existed from all eternity. Hence the question to be considered is,—What was that something? And to this there appear to be only three possible replies.

1. First, we may say that Matter was the eternal thing—matter, that is, endowed simply with all the ordinary physical and chemical properties—and that this matter in due course gave origin to Mind. (For the moment I am using the term "Mind" in a somewhat indeterminate sense as indicating either a single mind or a number of minds, and again without specifying whether the mind or minds should be regarded as self-conscious or otherwise.)

2. Or secondly, we may say that Mind was the eternal thing, and that in due course it gave origin to Matter.

3. Or thirdly, we may say that they were both eternal.

As to the first of these alternatives, I think we may dismiss it at once on the strength of what has been advanced in previous chapters. Life exists—it most certainly exists upon the Earth—and, as we have again and again seen, it absolutely refuses to be explained along purely mechanistic lines. It is only by assuming an unseen, a psychical cause, that we can arrive at any sort of an understanding of it, whether we

approach the question from the physiological, the embryological or the evolutionary point of view. But this being so, the Mind or minds, which we are constrained to believe in, in order to account for Life, could never at any time have been produced by mere matter. Therefore, in some form or another Mind must have existed from eternity, and the first of the above three alternatives must be ruled out.¹

If, now, we adopt the second alternative, and say that Mind was the eternal thing and that in due course it gave origin to Matter, it leads straight to theism, and not only so, but to belief in one God rather than to belief in many. This follows, because throughout the material Universe we observe an order which is everywhere essentially the same ; although possessed of an infinity of parts, it presents all the appearance of being a single, a self-consistent whole. Thus it is of the same stuff throughout, the chemical elements of which the heavenly bodies are composed being practically identical in them all, and identical also with those found upon the Earth. This we know on the evidence of the spectroscope. The Law of Gravity, too, is everywhere the same, compelling the components of all the various binary systems, however distant, to acknowledge its sway, just as in the case of those bodies much nearer to us, viz. the planets and satellites belonging to the Solar System. Again, light coming from regions as remote, perhaps, as the Milky Way, reaches the Earth at last with all its properties absolutely unchanged, although it may have taken many thousands of years to accomplish the journey. Moreover, the messages which it brings, when rightly interpreted, tell us that within the infinitesimally minute atoms of which the stars are composed, the same intricate and exceedingly rapid movements are being performed, as in the atoms of those substances with which we can experiment on the Earth.

These and a number of other similar facts all point to but one conclusion, viz. that *if* it was Mind which alone existed from eternity and eventually brought into being the

¹ "While it may be possible setting out from mind to account for mechanism, it is impossible setting out from mechanism to account for mind."—James Ward, *The Realm of Ends*, p. 18.

world of matter, it must necessarily have been a Single Mind. Nor can we think of it otherwise than as a Mind in complete possession of itself—that is, a fully conscious Mind, and able, therefore, to foresee and to design, and to carry its designs into effect.

The third alternative admits of several possibilities, according as we conceive of the relation in which Mind and Matter stand to each other. We may suppose, first, that Matter, although eternally existing alongside of Mind, has been eternally produced by it. That is, the Physical Universe with all that it contains is the result of a continuous creative process ; it is a perpetual emanation from God. Or we may suppose that Mind and Matter are simply two different aspects of the same Eternal Reality—a theory which would closely correspond with that of Spinoza, who taught that Mind and Matter are the *attributes*, as he termed them, of the one underlying Divine Substance. Or again, we may suppose that they are, and that they always have been, two entirely distinct entities, each existing, so to speak, in its own right. In that case, however, it would have to be admitted, on the strength of what has already been shown, that Mind has operated upon Matter to at least this extent—that of moulding it into forms which it would not otherwise have assumed, viz. the bodies of plants and animals. But has Mind been the Originator of anything more than this ? It is a question which at once suggests yet another pair of alternatives. For we may either limit the action of Mind upon Matter to the production of organisms, and regard the vast inorganic realm of things as an eternal, self-existing, law-abiding whole—asking no further question as to how it came by its law-abidingness—or we may suppose that, to begin with, Matter was quite undetermined, and that it received from Mind whatever may now characterise it in the way of complicated structural arrangements and of orderly sequences of events.

Altogether, then, as the result of the above analysis, it would appear that there are the five following hypotheses to choose from :—

1. Mind alone has existed from eternity—the Mind of

God—and at a certain time He created the world of Matter, the so-called Physical Universe. He has also at various times brought into being numberless other minds subordinate to Himself.

B. God and the Physical Universe have both existed from eternity, but the latter has all along been entirely dependent upon God and continually, so to speak, proceeding from Him. He is, and always has been, its underlying, its unceasing Cause.

C. At bottom Mind and Matter are only different aspects of the same Eternal Reality. Each is the precise counterpart of the other.

D. Mind and Matter are two eternally distinct entities, neither of them having given rise to the other. Matter in itself, however, is entirely formless. Whatever in the organic or the inorganic realm it may now possess of form—that is, of distinct qualities, definite arrangements and of general law-abidingness—is due to the operation of Mind—the Mind of God.

E. The same as the last, but with this important difference, that Mind has only operated in the production of living beings. The inorganic Universe is something entirely apart—a colossal piece of mechanism working on incessantly in conformity with certain inflexible laws, our only attitude towards which must be one of resigned acceptance. It is to be remarked that on this theory a peculiar form of polytheism becomes possible. For if Life on the Earth is to be referred, as we have seen it must be, to some Superior Intelligence, why may not a number of similar but wholly unrelated Intelligences have been the cause of Life in other worlds, supposing it to have arisen in them? But, as I shall endeavour to show in the present chapter, this is an hypothesis which, along with the two preceding ones, *C* and *D*, cannot be sustained. Meanwhile, keeping that object in view, let us pass on to an altogether different set of considerations.

There is one thing of which we may be quite sure. It is that although Life for millions of years has established itself on our planet, there must have come a time when it

first made its appearance here, seeing that the Earth was originally in a molten condition, and hence at a temperature far too high for Life to exist on it. How, then, did it first arise? If, disregarding for the moment all that has been said above and in previous chapters as to its dependence upon Mind, we confine attention to what an observer on the Earth would actually have seen had he been present at the time, it is clear that *either* he would have seen Life arising apparently spontaneously out of lifeless Matter, *or* he would have witnessed its arrival in the form, say, of certain minute germs somehow brought hither from elsewhere.

Now both these theories have at different times had their advocates. The first of them, commonly known as the theory of *Abiogenesis* or *Spontaneous Generation*, was upheld by many far on into last century. Pasteur, however, the famous French chemist, proved by a series of carefully conducted and most exhaustive experiments that nutrient liquids, if properly sterilised and afterwards protected against the intrusion of foreign germs, could be kept for quite indefinite periods without the faintest indications of life appearing in them. On the strength, then, of these experiments, abiogenesis was declared to be impossible. Life could only arise from pre-existing life, and hence, in view of the exceedingly high temperature which the Earth originally possessed, it must necessarily have been brought from afar. But how had it been brought? That was the next question to be asked, and in reply to it the two following suggestions were thrown out, one by Lord Kelvin and the other by the Swedish physicist Arrhenius.

1. Lord Kelvin's idea was, that Life in the shape of minute germs had been brought hither by a meteorite, which had fallen on the Earth millions of years ago soon after its crust had become consolidated. It was further suggested that the said meteorite was probably a fragment of some world on which life had previously existed, but which had been smashed to pieces as the result of its collision with another body. It was pointed out, too, that minute germs are often peculiarly tenacious of life, retaining their vitality over long

periods of time and capable of withstanding considerable extremes of temperature.

Against such a theory, however, quite a number of objections may be urged. The chief objection, of course, is that it offers no solution of what after all is the real problem, viz. as to how Life in the first instance arose. Granting that it was brought hither by a meteorite, we should still want to know how it had originated in the world of which the meteorite was supposed to have been a fragment. Again, we have seen in the previous chapter how even a near approach to one another of two heavenly bodies is an exceedingly rare event. Still rarer, therefore, would be any actual collision between them. Even if we suppose such a collision to have occurred, life on one at least of the colliding bodies must by hypothesis have been present; and we have learnt from the preceding chapter on how very small a proportion of the heavenly bodies is this at any given time likely to be the case, seeing that the conditions to be fulfilled are so many. If, however, notwithstanding this, we assume that a meteor laden with germs was at length launched into space, how extremely remote was the chance that, after hundreds of years of wandering perhaps, it should have happened to fall at last upon the Earth, and on a spot favourable to the development of the imported germs. And would not any such germs have been inevitably destroyed by the excessive heat generated by the swift passage of the meteorite through the upper layers of our atmosphere? It is difficult, indeed, to believe that to a combination of improbabilities like this we owe the existence of Life upon our planet, and the starting upon its course of that wonderful evolutionary process which has finally culminated in Man.

2. The other suggestion referred to was put forward by Arrhenius. According to him the whole of space is more or less pervaded with a countless host of ultra-microscopic germs, which are continually being driven in all directions by light pressure. The Physical Universe is in fact full of them, although how they first came into existence is left unexplained. When, therefore, the Earth had reached a

stage at which the conditions were at last favourable, certain of these germs settled upon its surface, grew and multiplied there, and thus became the progenitors of all the different forms of animal and vegetable life which have appeared since.

Now obviously this theory—known as the theory of *Panspermia*—is far less encumbered with difficulties than the other, for it avoids most of its improbabilities. Moreover, it is interesting, inasmuch as it carries with it certain important implications. Thus it would render it practically certain that Life must be present in many other worlds besides our own. The germs in question, being universally distributed, would tend to produce results similar to those produced here, on whatever world they might happen to alight, provided that that world was in a fit state to receive them. Also, Life on such a world would probably branch out and in time display a multiplicity of forms analogous to those with which we are familiar on the Earth; and hence might very well give rise at last to intelligent beings in all essential respects corresponding to ourselves. Again, it would mean that Mind as well as Life must be universally present, for even in the simplest germ—so we have seen ¹—there is something which is of a mental nature, and may be termed, therefore, its “psyche,” although it may not have attained to distinct consciousness. Furthermore, it being impossible for any number of unconscious entities, such as the psyches, to combine together and set in motion a process so replete with purpose and so far-reaching in its ultimate consequences as Evolution, we should be obliged to conceive of them as somehow inhering in, or at least as being under the direction of, a fully conscious Superior Intelligence. And inasmuch as on this theory the germs are supposed to be present everywhere throughout the Universe, it would only be taking one step more to identify this Intelligence with the one Supreme Mind. Thus the theory of Panspermia, combined with what has been said in previous chapters, would seem to lead up naturally to monotheism, although it might still be doubtful as to which

¹ Chapter XXI.

of the different monotheistic types mentioned above it ought to be referred.

To tell the truth, however, neither of the above two theories receives much countenance at the present time. The whole trend of scientific opinion lies in another direction—viz. towards the belief that Life, instead of having been introduced from outside, must somehow have arisen spontaneously out of lifeless material, although in what sense exactly we are to understand the word “spontaneously” may well be matter for further consideration. It must not be thought, however, that on this account Pasteur’s celebrated experiments are to be regarded as nowadays of no value. Apart altogether from their practical bearing on the healing art, they are still of considerable theoretic importance. They at least warn us of the futility of expecting to see Life arise in the shape of either bacteria or protozoa in artificially prepared solutions, however long such solutions may have been preserved in sealed-up flasks or other vessels. It must be borne in mind in this connection that bacteria and protozoa, low down as is their present position in the scale of life, are far more highly organised than we might be inclined to think from just their appearance under the microscope. The protoplasm of which, in common with all the higher animals and plants, their bodies are chiefly composed is an extremely complicated substance, the complexity of which greatly exceeds that of the most complex chemical compound.¹ Consequently, if Life arose out of previously existing lifeless material, it is highly probable that all sorts of intermediate stages were passed through before anything in the shape of an actual cell appeared. As no molecule, however many hundreds of atoms it may contain, has ever yet been glimpsed under the strongest magnification, we may conclude that at most, if not all, of those intermediate stages nothing whatever would have been visible. Hence for the evolution of the primitive cell it may well be that many millions of years had to go by, coextensive perhaps with

¹ “It is quite certain that most of the Protozoa, even everyday forms like *Amœbæ* and Slipper Animalcules, are the results of long-continued evolution. . . . They are masterpieces of complexity.”—From Professor J. A. Thomson’s *System of Animate Nature*, p. 387.

those far-off archæozoic and proterozoic times which, according to Dr H. F. Osborn,¹ lasted as long as the whole of the immense period which has elapsed since.

The view above expressed formed the main theme of that memorable address on "Life, its Nature, Origin and Maintenance," which was delivered by Sir E. S. Schafer before the British Association in 1912. In it he said: "So far from expecting a sudden leap . . . from an entirely inanimate substance to a completely animate state of being, should we not rather expect a gradual procession of changes from inorganic to organic matter through stages of gradually increasing complexity, until material which could be termed living was attained?" Or to quote the late Dr Benjamin Moore, Professor of Bio-chemistry in the University of Liverpool, he says in his excellent little manual on *The Origin and Nature of Life*: "As Matter increases in degree of complexity and eventually becomes the basis of Life, it will begin to manifest new energy properties, and give rise to energy transformations and phenomena such as are never seen in inorganic Nature." And again he observes: "There exists a whole territory of approach between the inorganic and organic in what is known as the chemistry of the colloids." And once more: "It was no fortuitous combination of chances and no cosmic dust which brought life to the womb of our ancient Mother Earth . . . but a well-regulated, orderly development which comes to every mother earth in the Universe in the maturity of her creation, when the conditions arrive within the suitable limits." F. J. Allen, too, remarks: "Life is not an extraordinary phenomenon, not even an importation from some other sphere, but rather the actual outcome of circumstances on this Earth." Or if we require episcopal sanction, we have the late Bishop Mercer saying: "They"—that is, certain experimental results—"tend to show that so-called dead substances are not so much devoid of life as manifestations of life on a lower plane . . . or, to put the matter in another way, I should say that life sleeps in the inorganic world, stirs in

¹ See his article on "Palæontology" in the *Encyclopædia Britannica*, vol. xxxii.

plants, awakes in animals, and comes to self-consciousness in Man.”¹

According, then, to the authorities just quoted, the meaning of the term “Evolution” is to be extended, so as to include not only the organic, but the inorganic realm. We are to conceive, in fact, of the entire process as having been a continuous one all along, stage following stage in a perfectly orderly manner. Also in Evolution, thus understood, we may discern, I think, what may fitly perhaps be described as the *Law of Successive Aggregates*, the meaning of which I will endeavour now to explain.

We have already seen in Chapter III that the number of the so-called chemical elements is limited to about ninety, and that to each of these there corresponds a particular kind of atom. Further, these atoms by their combination with one another form molecules of all sorts of degrees of complexity. Sometimes a molecule may be extremely simple, consisting of two atoms only, as in the case of quicklime, the molecule of which is represented by the symbol CaO , indicating that it is made up of one atom of calcium and one of oxygen. At other times it may consist of several atoms, as in the case of water, H_2O , carbonate of soda, Na_2CO_3 , sulphuric acid, H_2SO_4 , ether, $\text{C}_4\text{H}_{10}\text{O}$, and quinine, $\text{C}_{20}\text{H}_{30}\text{O}_5\text{N}_2$, containing 3, 6, 7, 15 and 57 atoms respectively. Chlorophyll, again, the green colouring matter of plants, which plays so important a rôle in relation to life,² is still more complex, being a mixture of two substances, the molecules of which are represented by the symbols $\text{C}_{55}\text{H}_{70}\text{O}_6\text{N}_4\text{Mg}$ and $\text{C}_{55}\text{H}_{72}\text{O}_5\text{NMg}$,³ containing 136 and 134 atoms respectively, and yet for all their complexity so minute as to be absolutely invisible under the most powerful microscope.

Now the number of these compounds is practically infinite, for, besides the profusion of them found in Nature, our chemists have been able to build up an immense host of others, year by year adding continually to the list. Also

¹ J. E. Mercer, *The Mystery of Life*, p. 27, published by the S.P.C.K.

² See Chapter IV, p. 41.

³ For an explanation of these chemical symbols see Chapter III, p. 30.

—and this has its decided bearing on our present subject—it has been found possible to construct out of purely inorganic substances a large number of compounds which had previously been known to exist in the bodies of plants and animals only, and for the manufacture of which Life had hitherto been held to be absolutely necessary.

But if molecules are aggregates of atoms, atoms in their turn are aggregates of particles very much smaller, viz. of protons and electrons. All protons are believed to be alike ; so too are all electrons, and yet it is out of these two—these two only—that the entire Material Universe is supposed to be constructed. They form, so to speak, its ultimate building-stones.

Among atoms the hydrogen atom is by far the simplest. At its centre, and forming its so-called nucleus, there is a single proton, and around it, incredible as it may seem, a single electron is revolving 7000 billion times a second. Although these two components are only one five hundred millionth of an inch apart, it is easy to show by a simple calculation that every second the electron must accomplish a journey of some 1400 miles.¹ I may add that whereas a proton weighs 1845 times more than an electron, their electrical charges, although opposite, are exactly equal. A proton is positively charged, an electron negatively.

Helium, which in the order of the elements comes next above hydrogen, has within its atom a nucleus composed of four protons and two electrons, with two other electrons revolving round it like planets about the sun. After it, as we continue to ascend the series, come lithium, beryllium and boron, followed by carbon, which biologically is the most important element of all. Its atom consists of a nucleus of twelve protons and six electrons, with six other electrons circling around it. At the top of the series we have uranium with its ninety-two planetary electrons, and, only four places beneath it, we have radium with its eighty-eight. These last two elements, together with a few others not far from the top, such as thorium and polonium, possess radio-active properties—that is, their large unwieldy atoms

¹ For these figures see Bertrand Russell, *The ABC of Atoms*, p. 36.

are continually breaking up into simpler ones, and at the same time discharging multitudes of free electrons with a velocity equal to at least one-fifth of the velocity of light.¹

But if protons and electrons by their combinations with one another form atoms, and if atoms by their combinations with one another form molecules, we naturally ask,—Are there any aggregates of a still higher order? According to Dr Benjamin Moore, whose work we have already cited,² there exists an immense number of them. Molecules, it appears, are very apt to unite with one another to form multi-molecules, and of these we get a good though comparatively simple illustration in the case of the various alums. Ordinary alum, for example, is an aggregate consisting of one molecule of sulphate of aluminium, one molecule of sulphate of potassium and twenty-four molecules of water.³ In common with all the other alums it crystallises out from its aqueous solutions in beautifully shaped little octahedra. There are other multi-molecules, however, of a far more complicated kind known as colloids, which, like gelatin and the white of egg, refuse to crystallise, and are further distinguished by the fact that under certain temperature conditions they undergo coagulation. Now it is precisely these colloidal bodies which are the chief constituents of protoplasm, the living substance in every animal and vegetable cell.

Although up till now no one has ever yet witnessed the formation of living substance out of lifeless colloids—except under the immediate influence of living organisms—that does not exclude the possibility of its sometimes having happened when all the requisite conditions, at present quite unknown to us, were complied with. Indeed, that it must once at least have happened in the course of the Earth's history is almost a foregone conclusion, unless we are to fall back on one or other of the two theories already discussed, according to which Life was brought to our planet

¹ C. F. Rafferty, *Introduction to the Science of Radio-Activity*, p. 49.

² *The Origin and Nature of Life*, pp. 123–158.

³ The multi-molecule in this case contains 26 ordinary molecules, consisting in all of 96 atoms, and these of about 1900 protons and electrons.

from outside. But as already stated, the entire trend of modern scientific opinion is opposed to any such notion.

Granting, then, that at some remote epoch living substance did *to all outward appearances spontaneously* arise in consequence of the coming together under favourable circumstances of certain colloids, it by no means follows that, to begin with, this living substance took on the shape of animal or vegetable cells. The newly formed aggregates would probably occupy a somewhat intermediate position, and, just like atoms, molecules and multi-molecules, would be far too small to be visible under any magnifying powers, such as those which we now possess.¹ If, then, to give these hypothetical bodies a name, we choose to call them "Bioplaſts," we can draw up a list like the one below, in which the various kinds of aggregates are shown in the order of their first appearances and of their increasing degrees of complexity. Naturally, at the bottom of the list we have placed the protons and electrons.

TABLE OF AGGREGATES

VII. Multicellular organisms	.	.	Visible.
VI. Unicellular organisms	.	.	Visible through
V. Bioplaſts (hypothetical).	(Innumerable kinds.)		
IV. Multi - molecules (colloids, etc.)			
III. Molecules	.	.	Invisible.
II. Atoms (92 kinds)	.	.	
I. Protons and Electrons (2 kinds only)	.	.	

This table sufficiently sets forth what I had in mind when I referred above to the "Law of Successive Aggregates." I mean by it that tendency, *apparently* inherent in the ultimate particles of matter, which causes them not only to combine together and form atoms, but out of these combinations

¹ "There must exist a whole world of living creatures which the microscope has never shown leading up to the bacteria and the protozoa."—Benjamin Moore, *The Origin and Nature of Life*, p. 190.

to form higher and still higher ones in a gradually ascending series, till at last aggregates arise exhibiting all the phenomena of life.¹ As to how exactly in the course of evolution the transition was effected from I to II we do not know, although it is probably taking place even now in certain of the stars.² Neither are we any the wiser as to how the transition was effected from IV through V to VI. On the other hand, the transitions from II to III and from III to IV are continually taking place both in Nature and in our chemical laboratories, while the transition from VI to VII is the one which must have occurred when cells, instead of separating from one another after division, first began to cling together in cell-masses, and thus to render possible the coming in of all the higher multicellular plants and animals. It is to be noted, moreover, that our present inability to build up even the lowest forms of life out of colloidal substances is paralleled by our present inability to build up atoms out of protons and electrons.

It has been asked,—“Why should matter at only one period of the Earth’s history have given rise to living beings?” To which it has been replied that for anything we know it may repeatedly have done so. It is probable, however, that after the earliest forms of life, such as protozoa and bacteria, had once established themselves, they devoured whatever fresh materials on the borderland between the living and the non-living were subsequently evolved. There is a note to this effect at the bottom of page 19 in Sir E. S. Schafer’s Address, where he says: “Lankester conceives that the first protoplasm fed on the ancestral steps in its own evolution, and F. J. Allen comes to the conclusion that living substance is probably constantly being produced, but that it fails to make itself evident owing to the substance being seized and assimilated by existing organisms.”

Evolution, then, according to that aspect of it which we

¹ See Additional Note (No. 1) at end of this chapter.

² “In the stars there is strong reason to believe that the heavier elements are actually being built up from lighter ones under conditions involving phenomena of radiation and absorption of energy as yet unmatched on the earth.”—G. E. Hale, *Beyond the Milky Way*, p. 101. See also Harlow Shapley, *Starlight*, p. 75, and Sir Oliver Lodge, *Modern Scientific Ideas*, p. 55.

have just been considering, appears as a process in which the ultimate particles of matter have been slowly coming together and forming aggregates of continually increasing complexity. In this process there has been a succession of stages, the aggregates belonging to any one stage being built up of aggregates belonging to the stage immediately below. There is, however, another and far more important aspect of the Evolutionary Process to which attention must now be drawn. I refer to the fact that at each successive stage, properties altogether new have manifested themselves—properties the nature of which it would have been quite impossible to predict from any knowledge previously possessed of the properties manifested at any of the earlier stages. The best illustration of this is found perhaps among chemical compounds, the properties of which as a rule differ *in toto* from those of the elementary substances entering into their composition.¹

Let us choose for example the two elementary substances, sodium and chlorine. Sodium is a metal exceedingly soft and quite easy to cut with the knife. It floats upon water, and it will, if kept there in one position, suddenly catch fire and burst into a bright yellow flame. In relation to other bodies it possesses a strong alkaline reaction, and when vaporised assumes a violet colour. Chlorine, on the other hand, is an exceedingly heavy, greenish-yellow gas of a strong suffocating smell, very poisonous and possessing important bleaching properties. And yet, when these two highly dangerous substances unite, they form that entirely innocuous but extremely useful substance, common salt (NaCl), which we take in at almost every meal.

Again, the element nitrogen in its free uncombined state is a colourless, odourless gas which we are constantly inhaling in large quantities, seeing that nearly four-fifths of the air are composed of it. It is singularly inactive, and only slightly soluble in water; and yet when it is combined with the element hydrogen, another colourless, odourless, and only slightly soluble gas, it forms ammonia (NH₃), with its very characteristic pungent smell, its markedly

¹ This subject has been touched upon before, p. 32.

alkaline properties, and its high degree of solubility. Nitrogen, moreover, when combined in proper proportions with oxygen and hydrogen—those two elements which when united form water—produces that fuming and exceedingly corrosive liquid, nitric acid (HNO_3), which is one of the most powerful solvents known, capable of dissolving copper, iron, zinc, silver, and nearly all the other metals, gold and platinum and a few others being the only exceptions. Again, when combined in proper proportions with carbon and hydrogen, nitrogen forms prussic acid (HCN), the most deadly of poisons.

Once more, to confine attention to just the four elements—oxygen, hydrogen, nitrogen and carbon—we know that they are capable of uniting with one another in an almost endless variety of ways, so as to form compounds differing as widely from one another as, for example, marsh gas, alcohol, ether, glycerine, acetic and tartaric acids, sugar, starch, benzene, aniline, nicotine, strychnine, menthol, indigo, camphor, etc.¹ But how are we to account for the appearance of all the remarkable and exceedingly diverse properties displayed by these various substances, if we are to say no more about them than that they are simply the result of the coming together in various ways of the atoms of the four elements in question? Of course, in a sense such a statement is perfectly true; but does it not look as though the coming together of the said atoms was the occasion, rather than the cause, of the appearance of all these new and very extraordinary properties? For the sake of argument let us imagine that the Universe had originally consisted of only four immense masses of material, each in a high state of incandescence—stars, in fact, one composed entirely of oxygen, another of hydrogen, and the other two of nitrogen and carbon respectively. Let us further imagine that after untold æons had elapsed, these four masses were at last drawn together by their gravitative forces into a single body, and that this body having sufficiently cooled down, the four elements began for the first

¹ For the formulæ of the molecules of these substances see Additional Note (No. 3) at end of this chapter.

time to combine with one another and to form a multitude of compounds such as those given in the above list. Now in what sense, I ask, would the properties of these compounds have possessed any real or even potential existence during that enormously extended period which had preceded their final appearance? Is it not clear, as we pursue this line of thought, that the molecules of compound substances must be something more than mere aggregates of the atoms entering into their composition? ¹ They are aggregates, it is true, but at the same time they furnish the conditions for the manifestation of certain hitherto entirely unsuspected aspects of that Unseen Reality, whatever it may be, which underlies them.

But the atoms in their turn are also aggregates. Each in its neutral, that is, in its so-called unelectrified condition, is composed of an equal number of protons and electrons,² all the protons and certain of the electrons constituting its nucleus, while the rest of the electrons are incessantly performing their revolutions round it. But here once more we want to know,—How out of combinations of this kind, in which only two sorts of ultimate particles are concerned, arise all those manifold qualitative differences which distinguish the elements from one another? Take, for example, the four elements, sulphur, chlorine, argon and potassium. Sulphur is the yellow substance with which, in the form of solid sticks or loose powder, we are all familiar. Chlorine I have already described as a greenish-yellow, suffocating gas. Argon is another gas, but without colour, taste or smell. It is extremely inert, more so even than nitrogen, refusing to enter into union with any other element. Potassium is a metal closely resembling sodium and, like it, spontaneously catching fire when thrown upon water. And yet these four, all so very different, stand in closest proximity to one another in the ascending order of the elements, the number of planetary electrons within their atoms being respectively 16, 17, 18 and 19. But how is it that differences

¹ "All real synthesis entails new properties, which its component factors in their previous isolation did not possess."—James Ward, *The Realm of Ends*, p. 102.

² When electrified there is a slight excess of either protons or electrons.

so slight in the number of their constituent particles—of which there are only two kinds—should produce, or at least appear to produce, all that marvellous diversity among the properties of the four elements in question?

Obviously we are confronted here with precisely the same kind of phenomenon as that met with in the formation of molecules out of atoms. At each stage in the process of aggregation there is the emergence of an entirely new and unpredictable set of properties, which the mere fact of aggregation does not explain, and which apparently rise up, as it were, out of some secret, Invisible Source. Is it, therefore, much to be wondered at that on nearing the highest stage of all—ordinary molecules having given birth to complex colloids, and these through certain intermediate bodies to protoplasm—there should finally appear, rising up from the same hidden Source, certain other remarkable and altogether unique properties, viz. those which distinguish living beings? But Life, as we have seen, implies Mind; and Mind, as it has continued to develop, reaching at last its fullest expression in Man, has revealed itself increasingly as purpose, choice, self-consciousness, definite personality. These things, then, owe their origin on our planet neither to extra-mundane causes nor to the mere matter of which the Earth is composed—if by “matter” we mean just that which is possessed of only the ordinary physical and chemical properties—but rather to that Unseen Reality of which so-called matter is but the superficial manifestation—the peculiar manner in which the said Reality presses in upon us, so to speak, through our sense organs. Just as when considering the brain we saw how impossible it was, and would always be, with these sense organs of ours to penetrate into its innermost nature,¹ so it is also, we may say now, in the case of all material objects whatsoever, whether they belong to the organic or to the inorganic sphere. Again, between these two spheres, apparently so sharply marked off from one another, we must no longer think that there exists any impassable chasm. The Evolutionary Process did not begin with those organ

¹ Chapter XXI, pp. 301, 302.

isms which are only just visible to us through the most powerful microscopes, but far down among the protons and electrons, the very foundation-stones of the Physical Universe. And inasmuch as the Evolutionary Process issued at last in the production of Life, and Life, as we have learned,¹ is inexplicable apart from some all-directing Mind, it follows that that same all-directing Mind must have been present on the earth from the very first, and that to Him, therefore, we must ascribe all the earlier, the inorganic stages of Evolution, as well as all the later, the organic ones.

Further, as confirming the above conclusion, it has been pointed out in an extremely interesting and comparatively recent work,² that while living beings have undoubtedly become adapted in all sorts of ways to the inorganic environment, the inorganic environment was, previous to their first appearance, being adapted to them, or—for it amounts to the same thing—was being got ready for their reception. This is well illustrated, for example, in the case of that universally diffused substance, water. Its specific heat, its expansion on freezing, its latent heat of evaporation, its remarkable chemical stability, and its unique properties both as a solvent and as an ioniser—all these are shown, in the volume just mentioned, to be the very properties which in a most extraordinary manner render it serviceable to Life. It is the same with the various properties of carbon dioxide, on which directly all plants, and indirectly all animals, feed ; and, as to carbon itself, it possesses that quite remarkable property which causes its atoms to cling together in long chains and other curiously shaped formations, thereby enabling those highly complex molecules to be formed which are so essential for the construction of living substance. But for full information on this highly interesting subject, and for the argument which may manifestly be built upon it, I must refer the reader to the book itself.³

¹ Chapter XXVI.

² *The Fitness of the Environment*, L. J. Henderson, Assistant Professor of Bio-chemistry in Harvard University.

³ See also Sir Oliver Lodge, *Ether and Reality*, p. 148 : "The ages of the Earth's past seem to have been a sort of preparation for the life and mind which now is, and for the mind which is still to come."

And now at last from all that has been said a most important deduction may, I think, be drawn. At the beginning of Chapter XXVII I remarked that while "it was one thing to have reached the conclusion that Life on our little planet could only be explained as the work of some Superior Intelligence, it was quite another thing to conclude of the Universe as a whole, with its illimitable spaces and its myriads of stars, each in size more or less comparable with our own sun, that it proceeded from the same source." But are we not now in a position to overcome this special difficulty, which indeed would never have suggested itself, if the Astronomy of to-day were no further advanced than it was a few centuries ago? For if, as we have seen, the Superior Intelligence which has been responsible for the Evolution of Life upon our planet, was likewise responsible for all those pre-organic stages in which matter was being rendered increasingly complex, then there is this further fact to be combined with it, that not only is the actual matter of the Universe as revealed by the spectroscope everywhere the same, but it is apparently evolving everywhere along practically the same lines. True, separated as we are at present by such enormous distances from all the other heavenly bodies, we cannot be positively sure that Evolution, in any other world besides our own, has reached that highest stage of all in which Life, and with it Mind, appears. We do know this, however, that in stars which have sufficiently cooled down, compounds are beginning to replace elements—atoms, that is, are uniting to form molecules¹—while in many of the hottest stars protons and electrons, if they have not done so already, are presumably coming together to form atoms. Thus that Power which has been at work in our own little world, building up out of simplest materials ever higher aggregates and therein revealing more and more of its rich underlying Essence, is seen to be one with that Power which throughout the Universe as a whole is effecting similar results. But this is the selfsame Power which, because of its manifestation of Itself in the world of organisms and in the world of

¹ In the red Dwarfs, for example (see Chapter XXVII), p. 407.

human life, we have already come to recognise as of the nature of Intelligence, and to which, therefore, we may now without any further hesitation apply the name of God. It is to Him, then, the one eternal, self-conscious, all-purposing Spirit, that we must attribute the entire fashioning of the visible Universe into its present shape, and it is by Him also that we must conceive of it as being perpetually dwelt in, actuated and sustained.

Finally, it remains for us to consider the bearing of the conclusion which we have now reached upon those five alternatives set forth at the beginning of this chapter. It will, I think, at once be obvious that alternative (*E*) is quite inadmissible, inasmuch as it limits the operation of Mind upon Matter to the production of living organisms, whereas, as we have just seen, Mind on our little planet must have been operating upon Matter during those long, well-nigh interminable ages before any organisms appeared.

We may also dispose of alternative (*C*), which represents Mind and Matter as simply two different aspects of some third, but altogether unknown, Reality. This involves a conception of the relation of God to the Physical Universe which is wholly irreconcilable with what I have tried to demonstrate above, viz. that Matter has been plastic in the hands of God, and that the entire Evolutionary Process has been due to His continually exerted activity. The world—that is, the sum total of material things and of material forces—may truly indeed be said to have its whole life and being in God; but it is an entirely different thing to say, and one for which we have no warrant, that the whole life and being of God are immersed in the world. He is immanent in it, but He also transcends it.

Alternative (*D*) is far less objectionable than either (*C*) or (*E*), but if adopted would land us in a sort of unnecessary dualism without yielding any advantage in return. It refers everything to the work of the Supreme Spirit except this—the bringing into existence of the raw material out of which the Universe has been gradually formed. But why stop short just at that point?

As to (*A*) and (*B*), the two remaining alternatives,

I conclude that the truth lies with one or other of them, although it may be difficult to say which. Much might be urged in favour of each, but the discussion would be hardly worth while, and especially as religiously regarded it can make no difference whether the Universe was called into being by God at some particular point of time, or is, and always has been, the result of His eternal activity.¹

The following is a brief summary of the argument contained in this and in the two preceding chapters :—

1. We cannot straight away identify the Intelligence, which has been the cause of Life on our little planet, with any Intelligence which may be supposed to have given origin to the Physical Universe as a whole. We cannot do so, because of the colossal scale on which the Physical Universe has been constructed.

2. It would considerably alter the case, however, if we could be assured that Life exists elsewhere than upon the Earth; but of this we have no positive proof. It may nevertheless be true, that on many other worlds, though by no means on all, the conditions are probably such as to render Life possible.

3. Seeing that our planet was originally in a molten condition, a time must have come when Life made its first appearance upon it. As modern scientific opinion is opposed to the idea that it was imported from outside, it follows that it must somehow have arisen in an *apparently* spontaneous manner out of inorganic, that is lifeless, matter already existing on the Earth.

4. Lifeless matter, like Life itself, has undergone a process of Evolution consisting of a number of successive stages.

5. In the manner in which these stages have followed one another we note (*a*) what I have described at some length above as the “Law of Successive Aggregates,” and (*b*) the appearance at each stage of an entirely new set of properties, the character of which it would have been impossible to foretell from any knowledge previously possessed of any or all of the earlier stages. Such properties, therefore,

¹ See Additional Note (No. 2) at end of this chapter.

cannot be the result of the mere aggregating tendency, but must proceed from some underlying Source.

6. Seeing now that in the last stages of all we have those special properties appearing which distinguish Life, and Life on the Earth can only be explained as the work of some fully conscious, purposing Intelligence, we are constrained to attribute to that Intelligence all the preceding inorganic stages, which indeed on Professor Henderson's theory were but preparing for Life when it should arrive.

7. Lastly, there is evidence to show that throughout the Universe generally, the same inorganic stages are being passed through as those with which we have become acquainted on our own little planet. The Great Power, therefore, which has been, and is still, effecting this, and whose operations can be traced far away among even the most distant stars, must be identical with that Power which, because of what it has finally accomplished on the Earth, we have been led to recognise as of the nature of Intelligence. Thus at last we reach the conclusion that there is, and can be, only One Supreme Intelligence from whom all things proceed, and whom in the language of Religion we have learned to speak of as God.

ADDITIONAL NOTES

Note 1.—There are certain other stages in the aggregating process which might perhaps have been included in the table given on page 439. Thus, as previously explained, tissues are aggregates of cells, organs are aggregates of tissues, and these organs are further built up into systems and system-groups.¹

Note 2.—It is to be remarked that the Hebrew word בָּרָא, *bārā*, which occurs in Genesis i, 1, and which is translated in our English version by "created," does not necessarily imply a "creation out of nothing," or a creation which was only effected at some particular time. Its root meaning, as given in the Lexicon, is "to cut," and from this are derived its further meanings, "to carve, fashion, make,"

¹ See Chapter XII, p. 143.

and even "to kill" (in the sense of "cutting down"). In the Old Testament we find it employed in all these senses. Moreover, in Genesis i, 1, the Septuagint translators have rendered it by the Greek word *ἐποίησεν*, which means simply "he made."

Note 3.—Formulae giving the composition of the compounds mentioned on page 442 :

Marsh gas	CH_4	Tartaric acid	$\text{C}_4\text{H}_6\text{O}_6$	Nicotine	$\text{C}_{10}\text{H}_{14}\text{N}_2$
Alcohol	$\text{C}_2\text{H}_6\text{O}$	Sugar	$\text{C}_{12}\text{H}_{22}\text{O}_{11}$	Strychnine	$\text{C}_{31}\text{H}_{22}\text{O}_2\text{N}_2$
Ether	$\text{C}_4\text{H}_{10}\text{O}$	Starch	$\text{C}_6\text{H}_{10}\text{O}_5^*$	Menthol	$\text{C}_{10}\text{H}_{20}\text{O}$
Glycerine	$\text{C}_3\text{H}_8\text{O}_3$	Benzene	C_6H_6	Indigo	$\text{C}_{16}\text{H}_{10}\text{O}_2\text{N}_2$
Acetic acid	$\text{C}_2\text{H}_4\text{O}_2$	Aniline	$\text{C}_6\text{H}_7\text{N}$	Camphor	$\text{C}_{10}\text{H}_{16}\text{O}$

Note 4.—Quite recently R. A. Millikan and G. H. Cameron have brought forward evidence tending to show that on the Earth even at the present time atoms of Helium, Oxygen, and Silicon are being built up out of Hydrogen atoms, as the result of the impact of the so-called "cosmic rays." These rays are of extremely short wave-length. See the *Proceedings of the National Academy of Sciences*, June 15, 1928.

* Or some high multiple of this (see Chapter III).

SECTION VII. ETHICAL AND RELIGIOUS

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CHAPTER XXX

GOD, THE UNIVERSE AND MAN

IF, as we have learned, the Supreme Power in the Universe is of the nature of Intelligence, are there any other ways in which we may legitimately conceive of Him? Is He, in a manner corresponding to what we find in ourselves, possessed also of Will and Emotion? In what general relation does He stand to the world at large and to ourselves in particular? Is the world, and are we, of any real value in His sight, or are we no more to Him than are the motes which people a sunbeam? These are a few of the exceedingly important questions which we have now to consider and try to find answers for.

That He must be possessed of Will would seem evident from the fact that the image of the Universe, which we are compelled to think of as originally present in His Mind, has already attained to at least partial realisation. That surely implies a voluntary putting forth of power by God—the result of a decision on His part, that a world such as ours should actually exist.

It is well perhaps here to emphasise the fact that the translation, so to speak, of the inner Divine thought into outer reality has only very gradually been accomplished, and that even now it is very far from being complete. It is possible, however, to imagine things to have been ordered differently. God might have willed a world into existence which would have been perfect from the first, and exempt, therefore, from all further change—a world as still and motionless as those mysterious recumbent figures of “Twilight and Dawn,” the work of Michelangelo in the Church of San Lorenzo at Florence. Not thus, however, by such

sudden act has the Physical Universe come into being. On the contrary, the creative process has spread itself out over incalculable æons of time, and is apparently still moving forward to some far-distant and as yet only very dimly perceived goal. Hence we may have to consider further on, what may be the possible significance of this, and why a world absolutely flawless should not have been called into existence from the first.

It may be said in reference to the Divine Will, that although in the organic domain there have been, and still are, manifold signs of its activity—as more particularly in the production of new purposive structures and in the rise of higher and still higher forms of life—such signs are wholly wanting when we get out into the Universe at large, which, with its unswerving obedience to law, appears rather as a colossal piece of mechanism than as a system under the constant supervision and control of a Supreme Mind. The inflexible order which confronts us there apparently leaves no room for the exercise of any Divine initiative.

To this in the first place it may be replied that, until in the course of Evolution the organic stage was reached with all its endless complications—arising chiefly out of the fact that now for the first time a certain measure of independence and of spontaneity of action were being granted to creaturely forms of existence—there was no reason why the Divine Will should have expressed itself otherwise than along certain lines determined upon once for all. The waywardness and uncertainty, which so often characterise human conduct, cannot be thought of for a moment in connection with an infinite and all-wise Intelligence to whom the future, as well as the past and the present, must be supposed continually to lie open. As to why, when Life had once dawned upon the scene, it was the Will of the Almighty that the already established laws of the inorganic Universe should remain in full force—the cause very often of events so disastrous to life as earthquakes and volcanic eruptions—is a question to which I hope to return in a later chapter.

There is another consideration to be borne in mind. The

appearance which the world presents of an absolutely unchanging order is largely due to the extreme brevity of human life, as compared with the enormous lapse of time during which the Evolutionary Process has been running its course. If only the successive stages in that course had been made to pass quickly enough before our eyes, the impression conveyed would have been very different from what it is apt to be now. We should have been struck instead with the extraordinary progressiveness of all that we saw taking place; we should have found ourselves perpetually on the look-out for whatever might be the next new thing which the Universe was on the point of bringing forth. Our attitude, indeed, would have been like that of one who is watching, say, for the first time the development of some living organism—a chick, for example, which in three short weeks passes through all its various stages, and from being a minute mass of almost exactly similar cells becomes the highly differentiated little creature which finally steps out of its shell.¹

Now according to a recent calculation by Barrell,² we are given to understand that the Earth's age—*i.e.* the period which has elapsed since the earliest sedimentary rocks were first laid down—cannot be much less than 1200 million years. If, then, we say of the historical period that it has lasted some 8000 years—which is probably a considerable overestimate—it follows that the former period must have exceeded the latter by 150,000 times. Let us imagine, now, the flight of time to be so accelerated that 1200 million years would seem no longer than the three weeks required for the development of a chick's embryo—what according to the same reckoning would be the proportionate length of the historical period, which is all that Man has had for the carrying on of his observations? It will be found to work out at about twelve seconds. Consider, then, how impossible it would be for any one to detect in a chick's embryo, during so brief an interval as twelve seconds, the slightest indications of progressive change, such as might lead him

¹ See Chapter II, p. 14.

² *Encyclopædia Britannica*, vol. xxxii, p. 10.

to infer that any process of development was going forward. The illustration, perhaps, may serve to make clear the point now under consideration, viz. that that appearance of absolute fixity in her ways of working which Nature is so apt to produce in us, is largely the result of the brevity of human life, and of the brevity, indeed, of the entire period during which Man has been here on the Earth. That period shrinks into utter insignificance when compared with the immense cycles of time which preceded it; and hence in part arises our inability to perceive in so many of the things happening around us any unmistakable evidence of the working of a Superior Will. Moreover, it is to be remembered that all our estimates of time are of a purely relative character—a truth of which the old Hebrew psalmist appears to have had more than an inkling when he said, addressing the Almighty, “A thousand years in Thy sight are but as yesterday when it is past, and as a watch in the night.”

There is yet another cause tending to conceal the fact that the Will of God is really operative in the world around us. It is that He, the Supreme Agent, acts upon things, not as we do from without, but from within, and that, therefore, He is continually, as it were, eluding our sight. Whereas in all cases of human construction—in the erection of a building, for example—we can watch the workmen as they go about their several tasks, first bringing to the spot all the necessary materials, and then employing them in such a manner as to carry out the architect's design, there is nothing in the least answering to this in the case of the Divine activity. “The hands which reach through Nature moulding man,” and moulding all things else into shapes of use and beauty, are absolutely invisible to us, and this because God is not a Power apart from and external to His Universe, sitting somewhere aloft in lonely splendour, but constitutes rather its innermost Being and Life. His is that sublime Presence of which Wordsworth was aware when he sang of—

That something far more deeply interfused,
Whose dwelling is the light of setting suns,

And the round ocean and the living air,
And the blue sky and in the mind of Man ;
A motion and a spirit that impels
All thinking things, all objects of all thought,
And rolls through all things.

Lines written near Tintern Abbey.

But to proceed. In addition to Intelligence and Will, is there anything in the Divine Nature which corresponds to Emotion in ourselves ? To many it will seem perhaps that, apart from some direct Revelation on the subject, it is in vain to expect any answer to such a question. Let us turn, however, to a certain aspect of the Universe to which we have hitherto given but scant attention. I refer to the way in which it makes its appeal not only to our intellectual faculties, but to the emotional side of our nature, awakening in us feelings of wonder and admiration and sometimes of the keenest delight. This is because, besides exhibiting in every minutest detail the most consummate workmanship, it is full also of surpassing beauty—a fact to be taken duly into account by any philosophy laying claim to our acceptance. To this I may add that if we are under immense obligation to our men of science for all those remarkable discoveries which are the result of their investigations, we are under an obligation scarcely less to our great poets and painters, who especially in these latter times have opened our eyes afresh to all the grandeur and exceeding loveliness of the world in which we live.

There is no need that I should enlarge here on the various elements which are supposed to enter into the idea of the beautiful. The principal ones are these : Unity in Diversity, Symmetry, Harmony of Parts, and certain other qualities suggestive of Infinitude, Mystery, Perfection, Power and Repose.¹ When everything, however, has been said by way of attempted analysis, we seem no nearer to any real explanation of the emotional effects produced. What is it that so moves us when we listen to the roar of the breakers on the beach, or in the stillness of the night to the song of the nightingale ? Why should “our hearts leap up

¹ Consult, among other works, Ruskin's *Modern Painters*, vol. ii.

when we behold a rainbow in the sky"? Whence that sudden rush of feeling—so impossible to put into words—as we watch the continually changing colours of some magnificent sunset, or try to take in the sublime spectacle of the midnight sky?

There is this important difference to be observed between the works of the Almighty and those of Man. The latter fall, as a rule, into two distinct classes. There are those which, like the printing-press, the steam-engine and the dynamo, serve a purely utilitarian purpose, and there are those which, like poems, pictures and pieces of music, are intended to arouse in us the sentiment of the beautiful. In the first of these two classes it is man's ingenuity and mechanical inventiveness which are in chief requisition, whereas in the latter what is needed is not simply technical skill, but that heightened state of feeling, often spoken of as inspiration, which grows out of the contemplation of, and delight in, all things fair and lovely. Sometimes, indeed, as in noble architecture, we find the useful and the beautiful blended together, but as a rule in works of human origin the two are only met with in isolation from each other.

But with the works of God it is most markedly different, for in them we get the perpetual interweaving of the two elements in question. Somehow, whatever may be the explanation of it, the Universe has been evolved in such a way as to fulfil an almost infinite number of useful ends, and at the same time to produce an almost inexhaustible display of beauty. But how has this result been brought about? Is it owing to mere chance, to a series of entirely unintended coincidences? Did the Almighty, I mean, in His fashioning of the world aim only at constructing a gigantic piece of machinery which should subserve every kind of utilitarian purpose; and did all the glory of the world, with its delicate passages of beauty and with its sometimes appalling splendour, insert itself into the general scheme by pure accident, having formed no part of the original Divine plan?

To me at least such an hypothesis is wholly inconceivable,

when once on quite other grounds we have risen to the belief that God really is, and that it is He who has ceaselessly been at work during all the past evolutionary ages. Surely He must have purposed the beauty which is in the world as well as all its manifold uses ; we must think of Him not only as Supreme Mechanician, but as Supreme Artist as well.¹

But further, we may regard it as an axiom that no great poet, painter or musician ever yet produced anything really beautiful and capable, therefore, of imparting joy to others, unless he himself had felt joy in the creation of it. He can be no true artist in whom the love of loveliness is wanting, for it is only out of the love of loveliness that anything truly lovely can be born. The poet who, like Shelley or Wordsworth, is to set our hearts aglow by unveiling to us glories which before we had only very dimly perceived, must be no mere manufacturer of verses, but one who far beyond his fellows has dived into the secret of the world to fetch forth its things of beauty, and has been conscious in so doing of the strongest thrills of emotion. But if this be so, and I may be allowed to argue by analogy, the conclusion would seem inevitable, that the beauty of which the world is so full could never have been got into it, unless there had been a joy in beauty, even in God Himself, and a continual delight in the production of it. But what does all this amount to but to say, that in God there must be not only Intelligence and Will, but likewise Emotion ?

It may be urged perhaps as an objection to the above, that beauty is after all only a subjective effect somehow wrought in us by the external world, and that we have no reason for supposing that the external world is beautiful in itself.

Well, for the moment let us grant that it may be so, and, indeed, in so far as the beauty of any object is dependent on its colour, there is something to be said on behalf of the contention.² But then the question immediately suggests

¹ " I can imagine some sort of a world coming of itself, spinning itself solid out of gases which had come of themselves ; but I cannot imagine such a world adorning itself as a bride for the bridegroom, which is what the real world is always doing."—Stephen Paget, *I Sometimes Think*.

² See Chapter XXI, pp. 295, 296.

itself, How was it that in a Universe, in which not even as a subjective experience had colour previously existed, were beings like ourselves at last evolved in whom this experience has now become so vivid? Or how was it that in a Universe, supposed to be devoid of all feeling for the beautiful, did the feeling for the beautiful eventually arise? Here, as in so many other cases, it seems impossible to extract from the Universe that which was not in some sense present in it from the beginning. From the beginning, then, must not the feeling for the beautiful, as also the enjoyment of it, have been present in the Mind of God?

But this opens up still further considerations. Thus it is hard to believe that that delight in the beautiful which has issued in the production of a world so fair as ours, is the only emotion of which the Divine Nature is capable. Why should there not alongside of it be others, as possibly, for instance, the emotion of love—a love going forth not only to the world at large, but to us human beings more especially, who on this little planet at least are unquestionably God's highest creatures? Now although at this stage we may not be justified in affirming positively that God's relation to us is one of love, we may be able nevertheless to make an important advance in that direction. And this we may do, because, as I shall now try to show, there is good reason to believe that both the world as a whole, and the human race in particular, are *of Value*, and indeed of very great value, in God's sight. If that can be securely maintained, we shall have reached a certain definite vantage-ground from which afterwards it will be possible perhaps to proceed further still. We shall be like the Alpine climber who at nightfall turns into the little hut half-way up the mountain side with the hope of gaining the summit on the following day.

That the world—*i.e.* the entire Universe—should be other than of value to God seems wholly incredible, when we think of all the labour which He has bestowed upon it during those incalculably long ages, when He was gradually fashioning it in accordance with His eternal plan. We know from our own experience how anything, on which

for several years we have lavished a large amount of our time and trouble, acquires a value for us which often far exceeds its mere money's worth. And if this be true sometimes of comparatively trivial things, like collections of certain natural and artificial objects, how much more is it true in the case of some supreme work of human genius. Consider the artist who has devoted all the better portion of his life to the perfecting of what he rightly regards perhaps as his chief masterpiece, and then think how keen, how overwhelming would be his sense of loss, if by any accident it should become irreparably damaged or destroyed. Or imagine what Milton would have felt, if after his completion of *Paradise Lost*, that great monumental work over which he had brooded for so long, and to the execution of which he had summoned up all his powers, some malicious person had committed his entire manuscript to the flames.

If, then, we men set a special value on anything which we ourselves have made because of all the time and toil which we have put into it, and set a value on it greater still, should it be something of an original kind, and bearing the peculiar stamp, therefore, of our own individuality, must not the same hold true of God in His relation to the world? It passes belief that His attitude towards it should be simply one of indifference, and that it would not in the least matter to Him, if it should suddenly cease to be, like some gorgeously painted bubble which, the instant you touch it, is gone. It is inconceivable that God, throughout the whole of His creative activity, should, according to a certain Hindu notion, have been merely amusing Himself, that He should have had no serious end in view, no far-off great goal, which He has all along been endeavouring to reach. It is just conceivable perhaps that a notion of this kind might have been entertained a few generations back, when it was thought that the entire Universe had been called into being in six literal days. In that case what God had so swiftly created, He might as swiftly and with scarcely any compunction destroy. Such a world could not have cost Him very much, and if anything at any time should happen to go wrong with it—well, it might perhaps be the best plan

to sweep it clean away and start afresh. But with all the knowledge which we now possess of the actual method of Divine creation, and of those immense cycles of time during which the creative process has been running its course, it would seem impossible to regard the Universe as being other than of value to God, or to imagine that without a pang He could permit it to pass away.

How far, now, may the argument which has just been employed be extended to the case of Man? Have we any warrant for believing that he also is of value to God? The answer to this question is not one which, like the other, we can quite so easily dispose of, for there are certain difficulties of a serious kind which crop up in connection with it. First, there is Man's apparent insignificance as compared with the gigantic dimensions of the Universe in which he finds himself placed. He is, after all, only an inhabitant—the chief inhabitant, it is true—of a somewhat diminutive planet circling round just one out of the many millions of suns scattered throughout space, and that sun by no means the largest or most conspicuous. Again his life—*i.e.* his life as an individual—is brief in the extreme, a mere moment in the immense eternity. What are his threescore years and ten in comparison with the time which it took, not only for this little world on which he lives to be formed and rendered habitable, but for the Solar System itself to be evolved, and the far vaster Sidereal System, of which it is but an insignificant part?¹ Or again, confining attention to the Earth, can we be quite sure that Man's supremacy on it is always going to last, and that some other being considerably more advanced may not hereafter arise, who will turn out to be the true goal towards which the Evolutionary Process has all along been leading up? Lastly, and still more serious, the question faces us,—How can Man be thought to be of value to God, to be really precious in His sight, when we reflect on all the havoc which sin and suffer-

¹ Sir J. H. Jeans, in a recent paper on "The Physics of the Universe" (*Nature*, Nov. 3, 1928), says that "the general age of the stars is probably between five and ten million million years." Taken at its lowest figure, this indicates a period 4000 times longer than the period given by Barrell since the Earth's sedimentary rocks first began to be laid down.

ing have wrought in human lives, and which surely He, the Almighty, might so easily have prevented?

Now it would be sheer folly if, like the ostrich which at the approach of danger is said to bury its head in the sand, we were to brush aside these difficulties as of no account. They must be fairly and squarely met. In the present chapter, however, I shall not attempt to deal with them, but shall try rather to set forth the argument on the positive side—to state, that is, the reasons encouraging us in the belief that Man, in spite of all that may be said to the contrary, nevertheless possesses value in God's sight. In the chapters which will follow I shall return to the difficulties, taking them up one by one.

If, then, for the present we dismiss them from our minds, let us consider the *enormous significance* of the fact, that here on this Earth at least the great Evolutionary Process has, past all question, culminated in Man.

It cannot be by mere accident that it has done so. For if, as we have again and again seen, Purpose has wrought itself in so unique a manner into the constitution of living beings, so that all their bodily functions illustrate it, and there is no single anatomical feature they possess which has not been fashioned by it, must not this likewise be true of the Life-system of our world as a whole? Surely it also must have a purpose—a supreme, an all-embracing purpose which God has had in view from the first, and which, so we can scarcely doubt, will ultimately be accomplished. Hence even if we should fail to discover what that supreme purpose is, the conclusion would seem forced on us, that it must somehow be bound up with Man, because, if for no other reason, he has come as the last link in the long evolutionary chain.¹ But if God's supreme purpose on this Earth is thus bound up with Man, Man must necessarily be of value to Him, and presumably of very great value indeed. I am referring more particularly here not so much to individuals as to the human race as a whole.

But further, Man occupies an entirely exceptional position in relation to all the other forms of life beneath him. What-

¹ See, however, Supplementary Note at the end of this chapter.

ever on purely anatomical grounds may be said about his close kinship to some of them, the indisputable fact remains that, in virtue of his vastly superior mental endowments, he towers immeasurably above them all. Thus he alone upon this Earth has attained to self-consciousness, to complete control of his inward thoughts and outward actions, to the power of forming general ideas and to the use of language for the expression of them; to judgment after due deliberation, to reason, to full freedom of choice, to the gradual acquisition of immense stores of knowledge and to the practical application of them, so as to satisfy his well-nigh endless needs and desires. In furtherance thereof he has invented tools of every possible description, elaborate machinery and instruments of the most marvellous precision. He has learned, too, to press into his service nearly all the powers of Nature—winds, tides, bottled-up sunshine, gravitation, steam, electricity. He has hewn down forests, tamed wild beasts, sown fields and gathered in their harvests, dug mines, constructed roads, bridges and fortifications, built towns and mighty cities, with the result that at the present time the whole surface of the Earth, save its desert wastes and polar solitudes, is covered over with the signs of his restless activity. Not content with these accomplishments, he has sought to penetrate into all the secrets of the Universe, to weigh the sun, to compute the distances of the stars, to measure the sizes of atoms, and to ascertain how the world, during the many millions of years which preceded his arrival, slowly came to assume its present state. Lastly, in every age there have been his incessant strivings after the ideal, his efforts to realise the dreams which have haunted him of the perfectly beautiful and of the absolutely good.

How, then, are we going to interpret these facts? It seems impossible to suppose that the final appearance of Man, endowed with all these wonderful powers, should have been the result of mere chance, and that it should have had no meaning, no special significance, for God. Rather must it have been part of His deliberate Will and Intention, that Man, when he arrived, should be possessed of all these

powers, and stand forth in consequence as the undoubted Head of the entire Animal Kingdom, nay more, as the very apex and crown of all His previous work. But if that was really so, need it be said that it tends to strengthen us enormously in the belief that Man must be of value, and indeed of very great value, in the sight of God?

It is worthy of note, too, in this connection, that in the Vegetable Kingdom there is no one species which occupies a position in it in the least answering to that which in the Animal Kingdom is occupied by Man. Among plants the natural order of the *Compositæ* is generally allowed to be the highest; yet who would dream of singling out either the sunflower, the chrysanthemum or the dahlia, or any of the other many thousands of species which the order includes, and of assigning to it a pre-eminence corresponding to that of Man?

Lastly, there is Man's moral and religious nature to be considered. We have to take into account his agelong search after God, and his continually renewed efforts by means of prayer, praise and sacrifice—not to speak of various ascetic practices—to put himself in living touch with his Maker, however imperfectly at times he may have conceived of Him. Can it, then, mean really nothing to God, all this persistent endeavour on the part of Man, His last and highest creature, to reach out towards Him—to feel after Him “if haply he may find Him”? Rather are we constrained to think, that it must stir in Him feelings of tender solicitude and loving regard, and especially in the case of those who, at pain and sometimes at great cost to themselves, have been striving to do the right, and striving to do it, because they believed it to be what He required of them. Is it possible to conceive that in the eyes of the Eternal there could be a more moving sight? Thus not only are we led up to the belief that the human race as a whole must be of value to God, but we are led up to the belief that there are probably countless individual members of the race of whom the same must be true in a far fuller and higher sense.

Nor is this quite all that may be said. We can scarcely

neglect here the testimony of Man's religious experience, varied as that experience has been in its intensity in different individuals. Taking, however, the typically religious man, I would refer to his sense of the Divine approval, whenever he has resisted those allurements which if yielded to would only have dragged him down, and he has chosen instead the clear path of duty in obedience to what he has somehow felt to be the higher call. I would refer also to his sense of the withdrawal of that Divine approval, whenever he has succumbed to temptation, and once more to his sense of the restoration of the same, after he has repented of the evil and has resolved henceforth to set his face steadfastly against it. Again, we have to take into account that vivid consciousness of the Divine Presence, coupled with feelings of inward security and peace and of a joy resembling nothing else, which has been attained by those who—to use the old Scriptural expression—have striven earnestly “to walk with God.”

Without, however, pursuing this line of thought any further for the present, I will only remark that, if it should be said of experiences of this kind that they are too vague and too intangible for anything solid to be built upon them, it is at least a reasonable hypothesis, after what has been said in the last paragraph, that they are of the nature of a Divine response to men's efforts so to live and act, as to bring their wills into increasing harmony with God's. If in any measure the love of God is drawn forth towards those who at much sacrifice are endeavouring to do His Will, what more likely than that He, who always works inwardly in things and inwardly also in Man, should grant them these inner tokens of His approval and regard?

SUPPLEMENTARY NOTE

I do not wish it to be inferred from anything said above that I think God's *only* purpose in the Evolution of Life was the final emergence of Man. It may well have been His main purpose, but I believe that there were other purposes besides.

May we not recognise, for example, in that vast profusion of forms which, quite irrespective of us, Life has displayed, the desire on God's part to express in this way something of the fulness and infinite resources of His own Nature? No doubt, many of these forms were intended to minister to our needs, but that does not in the least account for the almost endless diversity which they exhibit. Think of all the innumerable kinds which, unseen of Man, inhabit the ocean depths, and of how among the insect tribes alone there are said to be close upon a million species.

Again, the beauty of the world, as already remarked, is not solely for Man's delight, but for God's as well. Much of it never comes within human ken at all. As we are reminded in the famous Elegy,

Full many a flower is born to blush unseen,
And waste its sweetness on the desert air.

GRAY.

Who, moreover, until the invention of the compound microscope, was in the least aware of all the delicate grace of those multitudes of tiny organisms, often to be found in a single drop of water, such as, for instance, the Diatoms, the Polycystins and the Rotifers? And, once more, what explanation shall we give of all the beauty with which the world must have been full during those long well-nigh interminable ages before Man appeared?

CHAPTER XXXI

DIFFICULTIES

LET us consider now some of the principal difficulties which more or less hinder us from accepting straight away the conclusions set forth in the preceding chapter.

I. And first, we have to reckon with the possibility that some other being higher than ourselves may yet appear who will prove to be the true goal of the Evolutionary Process, and who will accordingly displace Man from his present unrivalled position. In that case the course of human affairs would have to be regarded as merely a passing episode in the general history of our planet.

Naturally, however, we ask, in view of such a possibility, —From which of the many already existing forms of life is this new prodigy going to arise? Will it be from any of those animals which, like horses, dogs and elephants, approach us most nearly in point of intelligence? The mere mention of such an idea is enough to convince us of its absurdity. And if we turn to the anthropoid apes, which anatomically stand closest to us, is it seriously to be believed that so unprepossessing a brute as either the orang-utan, the chimpanzee or the gorilla will eventually develop into a being superior to Man?

Clearly, then, if this higher being is ever to appear upon the Earth, he will somehow have to be evolved from Man himself, which at once makes us ask, —Is such an occurrence in the slightest degree probable? Its extreme improbability may be shown, I think, in various ways; and here in what follows I wish to acknowledge my indebtedness to the late Prof. Henry Drummond, who in his *Ascent of Man* has very fully discussed the whole question, and more particularly in his exceedingly interesting chapter entitled

“The Arrest of the Body.” The principal points to be noted are these :

1. Life has been evolved, as we know, along several divergent lines, and may be conceived of as a huge tree with numerous branches ending in a multitude of twigs, each twig representing a single species.¹ Now it would appear that along any one of these lines the possibilities of future development have their limits. Sooner or later there comes a time when changes of a fundamental character can no longer be introduced, this being particularly true of individual organs. It is very doubtful, for example, whether much improvement could now be effected in either the human hand or the vertebrate eye,² or whether the cavity of the skull could be enlarged so as to accommodate a bigger brain, without seriously encroaching on the face and interfering with the all-important organs of sight and hearing. There are limitations, moreover, of another kind. Thus in the great Chordate division, for the origin of which we must go back to Silurian times,³ it seems to have been ordained from the first that no member of it should possess more than two pairs of limbs. In fishes these are represented by lateral fins, and in nearly all animals living on the land by feet. In birds, however, and also in bats, the anterior pair have been converted into wings, whereas in ourselves the same pair have been converted into arms ending in highly flexible fingers. Thus in the Chordate division taken as a whole, limbs have been modified in such a way as to permit of four different kinds of movement, viz. swimming, walking, flying and the manipulating of objects. At the same time, no single member of the group can perform more than two of these kinds of movement, and for the reason just assigned, that the Chordates have once for all been constructed on a plan which admits of two pairs of limbs only. However much, then, we may deplore the fact that we are lacking in special organs for swimming and flying, we may feel quite certain that neither we, nor any of our descendants, are ever likely to be pro-

¹ See Chapter II, p. 23.

² See Chapters IX and X.

³ See Chapter XXIV, p. 361.

vided with them. Many other facts of a similar description might be quoted, but those just given will perhaps suffice.

2. Again, it would appear that it has been precisely Man's higher intellectual endowments which have rendered it now quite unnecessary that in his case at all events organic evolution—viz. that of the body—should proceed any further. Whatever process of an evolutionary kind may take place in the future, it will probably, therefore, follow along different lines.

To illustrate this point, Man, as we have just seen, has been unprovided with any special organs for either swimming or flying. True, he can swim after a fashion by putting his limbs to a somewhat unnatural use, but the performance at the best is scarcely a shining success. Long ago, however, to overcome this disability he hit upon a plan which has since led to certain highly important developments. "Why not build a boat," he said, "and fit it out with a pair of artificial fins, viz. oars?" But to row for more than a moderate distance was soon felt to be unnecessarily toilsome. So it was not long before another idea occurred. "Why not press the winds into my service and get them to do the thing instead? I will set up a mast and hoist a sail." The next step was to construct a still bigger boat—big enough to carry not only himself and his mates, but whatever else in the shape of merchandise he might wish to take to distant shores. And so the process has continued till, relying no longer on the fickle nature of the winds, he has learned to propel his Atlantic liners, not to speak of his smaller craft, across the ocean by the expansive force of steam. Hence there is now no need for him to develop special organs for swimming, just as there is now no need for him to develop wings, seeing that with the help of his aeroplanes and his dirigible balloons he has accomplished what previously would have seemed wholly impossible—he has solved the problem of how to fly.

But, again, Man soon grew dissatisfied with those special organs of movement with which Nature had endowed him. Hands and feet were by no means sufficient for all that he wanted to do, nor was he going to wait millions of years

on the chance that the slow processes of organic change might at last furnish him with others more to his mind. So one day instead of grabbing at the soil with his hands, he invented the spade ; instead of delivering blows with his fist, he bethought himself of the hammer ; instead of trying to tear things asunder with his nails, he chipped off a piece of flint, and behold a knife !—a very rude implement, no doubt, but the precursor, nevertheless, of the axe, the chisel, the scissors and the scythe, and of every other species of cutting instrument. Similarly, as the result of his ceaseless ingenuity, tools of every possible description one by one arose, followed in due course by the most complicated pieces of machinery, but all alike to be regarded as so many extensions, so to speak, of those bodily organs, his hands, with which Nature had originally provided him.

Moreover, Man soon found out that, however swift he might be of foot, he could not compete in this respect with many of the animals about him, as for instance with the horse. Then why not leap upon its back and get its legs to carry him instead of his own ? Also, why not construct vehicles which horses could draw ? Thus came gradually into use conveyances of every conceivable variety, from the war-chariot of ancient days down to the stage-coach, the brougham, the hansom cab and the omnibus. But horses, although they could outrun Man, could not outrun him fast enough. So the nineteenth century witnessed the arrival of the steam locomotive, which could cover a mile in a minute, and which prepared the way for that enormous development of the railway system which is so marked a feature of our own times. But all inventions of this kind—including of course the up-to-date motor-car—what are they but so many mechanical devices by which Man has increased his natural powers of locomotion ?

Much the same kind of thing may be said of that marvellous piece of mechanism for the production of speech, to which reference was made towards the end of Chapter IX. That the human voice can only carry a certain distance matters very little, when to-day we can converse with one another through the telephone and send messages by wireless to the

utmost ends of the Earth. Nor must we forget that far older, but perhaps most important of all human inventions, viz. written speech, by which knowledge of the thoughts and deeds of men of former generations has been handed down to us, and by which in a very real sense we are still able to listen to the voices of the mighty dead.

Thus with the advent of Man a stage has apparently been reached in which it is no longer necessary that the merely bodily organs should undergo further development. It is no longer necessary, because of the extraordinary command which Man has now obtained over his material surroundings—and to a large extent also over the limitations of space and time—in virtue of his superior mental powers. Or to give just one other illustration,—How long, may we ask, would it take in the ordinary course of events for an eye to be evolved which would enable us to see unaided all that can now be seen at a single glance through the Mount Wilson telescope with its enormous artificial eye—its mirror 100 inches in diameter?

3. I have hinted above that with the coming of Man a new era has probably begun in the history of Evolution. We are no longer to look forward to changes of a fundamental character affecting his bodily organs, but to changes of a progressive, but wholly different kind occurring within the sphere of his intellectual and moral being. In other words, Organic Evolution is now being succeeded by what can only be described as Psychic or Spiritual Evolution, with all that it involves in the shaping of outward circumstances and events. That an important turning-point of this kind has been reached is rendered all the more probable by the fact that another turning-point, in some respects corresponding to it, must have been reached millions of years previously, when Evolution passed on from its Cosmic to its Organic stage. Of course, as explained in Chapter XXIX, however wide may be the apparent gap separating the living from the non-living, we have reason to believe that the one must have arisen out of the other without any breach of continuity. Nevertheless, we cannot ignore the profound differences existing between them—differences,

indeed, so great that, when organisms first began to appear upon the Earth, it would have seemed to any observer who might have happened to be present then, as though Evolution were striking out for itself an entirely new path. Hitherto it had busied itself over the formation of vast bodies like the Sun and the Stars and of worlds similar to our own; now it began to busy itself over the formation of minute specks of protoplasm which possessed the remarkable property of producing other similar specks, and which were destined in due course to give rise to all the infinite varieties of animal and vegetable life that have since peopled the Earth. If, then, at that remote epoch Evolution began to pursue a path so markedly different from what it had pursued previously, why may not a time have arrived at last for another change equally significant to take place? In that case we should have to regard the entire process as being made up of three distinct stages, viz. the Cosmic, the Organic and the Spiritual, each of the two earlier ones preparing the way for the one which was to follow next. Now if we adopt this view, it renders it all the more improbable that any being *organically* higher than Man will ever succeed him on the Earth. Rather will it be within the sphere of his intellectual and moral nature that any further progress will be likely to take place, and that we must look for Evolution gradually to accomplish its highest ends, whatever those highest ends may turn out to be. As Sir J. Arthur Thomson puts it: "While there is definite evidence of progressive variation in Man, there is nothing to lead us to believe that any marked change will be wrought in Man's highly finished bodily frame. Everything appears to point rather to the conclusion that the line of human evolution will be that of increasing utilisation and command of the brain, with which there will doubtless be correlated an improvement in the social framework which forms Man's external heritage."¹

4. There is another point. In view of the immense progress which Man has already made—compare, for example, the mind of a Sir Isaac Newton with that of a

¹ See Harmsworth's *Natural History*, p. 156.

primitive savage—it may possibly be asked,—What is there to hinder progress being made quite as great, or perhaps even greater, in the course of a few more thousand years? And if that should come to pass and the human race as a whole should participate in it, would not the very name of “Man” cease to be applicable to the beings thus transformed? Against such a view, however, the following consideration may be set. Man, in virtue of all his many gifts and capacities enumerated in the previous chapter, is already in possession of a fully rational mind, and has thereby reached a level which puts him on certain terms of equality with all other rational minds, wherever they may happen to be throughout the Universe. To minds so constituted not only are all the logical and mathematical truths necessarily the same, but their thinkings on every sort of subject, in so far as they observe and reason correctly, will tend to coincide, and to coincide ultimately with what God also thinks. Hence Man will in essence always remain Man, to whatever heights of intellectual and moral excellence he may hereafter attain. And herein lies perhaps, at all events in part, the profound meaning of that ancient Scripture which asserts that Man was originally created “in the image of God.”

II. The astronomical difficulty which we have next to consider arises, as we have seen, out of the apparent insignificance of Man, as compared with the gigantic scale on which the Universe has been constructed. No wonder if at times we should feel overwhelmed by the comparison, and should begin to ask ourselves because of it,—Is it really possible that we can be of any value to God?

1. Now the first and most obvious thing to do, when our thoughts take this turn, is to remember that the little things of the Universe, such as those which can only properly be seen through the microscope, are in their way quite as wonderful as any of those big things on which we employ the telescope. Not only so, but it is precisely in these little things that the beauty and extreme delicacy of the Divine workmanship are often most strikingly shown. In a space no bigger than a pin's head hundreds of diatomaceous

shells may be gathered together, each of them appearing to the naked eye as an almost invisible speck of dust, and yet under sufficiently high magnifying power exhibiting the most exquisite perfection of form and of surface chiselling. Or take the wing of the Peacock butterfly. The gorgeous pattern which it displays is due to what can only be described as a most elaborate piece of mosaic work, composed of nearly 50,000 differently coloured scales, which are arranged in rows overlapping one another like the tiles on a roof. Each of these scales is marked by twenty or more very fine parallel lines about the $\frac{1}{12,000}$ th of an inch apart, and drawn with almost mathematical precision. It is these lines which in certain other species of butterfly impart to the wing its brilliant iridescent hues. Again, take the beetle's eye, the diameter of which is only a small fraction of an inch. We are assured in the case of the genus *Mordella*¹ that it is made up of no less than 25,000 facets, each with its own little lens and its tiny nervous filament. But the shell of the diatom, the wing of the butterfly and the eye of the beetle are, equally along with the mightiest star, the products of the Divine Power and Intelligence—a consideration which should wean us from the somewhat childish habit of thinking that the big things of the Universe are necessarily of greater importance than the little ones. "Big" and "little" are, after all, only relative terms, and in the eyes of the Eternal the little thing may often, for anything we know, possess far the greater value.

Again, marvellous as is the perfection to which the modern microscope has been brought, it is incapable of reaching down to those minutest particles of all—viz. the molecules, atoms and electrons, etc., which were referred to in Chapter XXIX. Although there can be no doubt as to their existence, they have never yet been sighted under the strongest magnification; nor is this in the least surprising, when we learn that it would require 250 million atoms arranged side by side to cover a distance equal to the breadth of a halfpenny.² Or if we take the Sun, the

¹ Louis Figuier, *The Insect World*, p. 2.

² Sir Oliver Lodge, *Modern Scientific Ideas*, p. 25.

diameter of which is put at 864,000 miles, and take the electron—examples respectively of some of the largest and the smallest bodies in the Universe—and ask, What would be the dimensions of a sphere as many times greater than the electron as the Sun is greater than it?—we get the remarkable answer, that such a sphere would be no bigger than $\frac{1}{18}$ th of an inch in diameter, or only about the size of a small shot. In other words, as between the Sun and the electron, the shot would form what is known as the “geometrical mean.”¹ Similarly, as between the Solar System² and the electron, the geometrical mean would be represented by a ball only $5\frac{1}{8}$ inches in diameter. These illustrations may help perhaps to convey some sort of a rough idea of the well-nigh infinitesimal dimensions of those ultimate particles out of which, along with the still more minute protons, the entire fabric of the visible Universe has been built up. Their importance, therefore, can bear no kind of relation to their mere size.

2. It would appear from what has just been said that Man physically considered occupies a kind of midway position between the infinitely great and the infinitely little—a fact which can scarcely be without some sort of significance. If his body were as big as the Moon, he might learn rather more perhaps about the Stars and the Sidereal System generally, but he would probably require a powerful lens to see a city of the size even of London. If, on the other hand, his body were no bigger than an ant’s, he might be able with a good microscope to obtain a glimpse of the molecules, but his astronomical knowledge would remain a complete blank.³ As things are, however, he occupies a kind of midway position between the two infinities.

3. But further, in reference to the things which God has made, their relative importance, far from depending upon mere size, depends rather upon the intricacy and perfection of their several parts, as also upon the harmonious manner in which these parts work together for the accomplishment

¹ To find the geometrical mean of any two numbers multiply them together and extract the square root.

² Reckoning its diameter to be equal to that of Neptune’s orbit.

³ Prof. Eddington, *Stars and Atoms*, p. 9.

of definite ends. The same holds true of articles of human manufacture. Thus the brass letter-weight which serves to keep my papers together on my study table is many times bigger than my watch, but my watch is by a long way the more valuable of the two, because of the elaborateness of its internal construction and of the accuracy with which it fulfils its purpose of telling the time. Now in the Universe at large, which is of God's making, this elaborateness of construction attains its highest development in the bodies of plants and animals. Thus the human body, with all its wonderful and most complicated arrangements, possesses in this respect an importance that far exceeds that of a block of marble, which is practically homogeneous throughout, although it may weigh perhaps several tons. From this once more we learn that mere size is by no means the thing which chiefly counts.

4. Again, as we saw in Chapter XXIX, the final emergence of Life, and along with it of Mind, was preceded by a number of stages which we can only regard as having been preparatory to Life, and for the sake of Life, whenever Life should appear. But if the creative process be indeed the work of God, then what He does last must exceed in value—so we seem bound to think—whatever He may have done previously. Else why, having brought the inorganic world into existence, should He have proceeded further—should He have gone on to create the innumerable forms of animals and plants, the entire process culminating at last in Man? This, as it seems to me, when combined with the arguments already advanced, helps to lessen very materially the so-called astronomical difficulty.

All tended to mankind,
And man produced, all has its end thus far ;
But in completed man begins anew
A tendency to God.

BROWNING.

5. Finally, it may be said that when once the level of mind has been reached, all considerations founded upon merely spatial dimensions cease to be of any relevance.

The mind is without dimensions, and hence its importance in the general scheme of things is on no account to be estimated by the size of that material structure, the body, with which it may happen temporarily at least to be associated, or which from another point of view may be regarded as its outward manifestation. As to the possible existence elsewhere in the Universe of other beings similar in intellectual and moral development to ourselves, no further difficulty need be felt, for wherever they may be and however much they may differ from us and from one another in outward semblance, they must all be essentially akin to us in mind, and must, therefore, be of the same value to God as we are.

III. The brevity of human life, as compared with the vast periods of geological time, and with the still vaster periods which preceded them, raises of course another difficulty. I do not intend, however, to discuss it here, but to let it stand over till we come to the last chapter of all, when we shall have to consider what grounds there may be for belief in a future life. Clearly in reference to this particular question it makes the whole world of difference, whether man's career terminates at death, or is to be continued, and perhaps indefinitely continued, beyond the grave.

IV. The last and most formidable of the difficulties, inclining us to doubt whether after all man can be of any value to God, arises out of the sin and suffering which have so seriously invaded human life—an invasion which, if the Almighty had but willed otherwise, would assuredly never have occurred. We are confronted here, of course, with the world-old problem of the Origin of Evil, which in every age has so greatly exercised the minds of Earth's wisest and best. Hence it may seem almost presumptuous on my part to attempt to add anything to what has already been said upon it. Nevertheless, it may be possible, working along certain lines, to gain some amount of fresh insight into the question, sufficient at all events to dispose of the greater part of the difficulty. To this most important subject, therefore, I propose to devote the next few chapters.

CHAPTER XXXII

EVIL AND ITS SOURCES

IN considering this subject, we have first of all to distinguish between sin or moral evil on the one hand, and suffering on the other. Although we frequently apply the term "evil" to them both, we must be careful not to confuse them together. Moral evil is only possible in the case of those who like ourselves are conscious of the difference between right and wrong, are endowed with freedom of choice, and who acknowledge the right as possessing a certain authoritative claim upon them. We express the same thing when we say of the right, that it indicates the line of conduct which under the given circumstances *ought* to be pursued. On the much vexed question, as to what really constitutes the right, I shall have something to say in the next chapter, as also upon the other question as to what we are to understand by the "conscience" or "moral sense." For the present it will be enough to content ourselves with the meanings which in a vague sort of way we generally attach to these expressions.

Suffering—that other and totally distinct form of evil—is by no means confined to ourselves, but extends far down among the animal tribes, although it must vary greatly in intensity according to the degree of development of the nervous system. It is probably quite absent among the lowest tribes of all, such as the Protozoa and the Cœlenterates, although some have imagined that there may be a sort of dim consciousness of pain, as also of pleasure, even among plants.

It is my faith that every flower
Enjoys the air it breathes.

WORDSWORTH.

Suffering is of two kinds—physical and mental. The former, which may range from a feeling of slight discomfort up to the most acute agony, is due to several causes. Sometimes it may result from the imperious and constantly recurring needs of the bodily system—*e.g.* for food, for drink, for sleep, for sufficient warmth, etc.—needs which, if left too long unsatisfied, may produce very serious consequences. Again, there are the sufferings occasioned by injuries of all sorts, whether accidentally incurred or purposely inflicted. These include bruises, burns, wounds, broken limbs, and the tortures of the rope, the rack and the wheel. Then there are the countless diseases to which, unfortunately, we are all more or less liable, and the many minor ills which with advancing years tend to accumulate and to give warning of the approach of death. Finally, there is death itself, which apparently ends all.

As to mental sufferings, their name is simply legion, and they pass into one another by almost imperceptible gradations. Such, for example, are those occasioned by fear, horror, loathing; anxiety, vexation, ennui; the sense of injury, hate, desire for vengeance; jealousy, the bitterness of unrequited affection; the grief occasioned by the loss of friends and of those whom we have held most dear.

It is to be remarked that our sufferings are often greatly aggravated by the way in which “we look before and after.” We live in the past and in the future, as well as in the present. Thus our hearts are saddened as we call to mind the happiness which was once ours, but which we fear will now never return; and we look forward with increasing apprehension to any painful experience which we may shortly have to go through, *e.g.* a surgical operation. Again, when racked with bad toothache, it is not merely the present pain which renders it so intolerable, but the thought of the many hours during which perhaps we shall have to put up with it before we can gain relief. Or consider the feelings of any one who has just been sentenced to twenty years of penal servitude.

Among the animals beneath us in the scale of life mental suffering must be enormously reduced as compared with

what we ourselves have to endure, and this largely because in them the above-mentioned faculty of "looking before and after" is only very imperfectly developed. Again, among the great majority of the invertebrates it is extremely doubtful whether there can be anything in the nature of mental suffering at all. It is difficult to think of it as existing in an oyster or a jelly-fish.

In addition to the evils which may be classed under either sin or suffering, there are others which are due to the circumstance that the Universe is in every part of it subject to the Law of Incessant Change. Nothing in it for a single instant is ever really still, from the inconceivably swift revolutions of the electrons inside the atoms up to the stately and somewhat more leisurely movements of the heavenly bodies.¹ Now although the changes perpetually going on do certainly in the main make for progress, they are frequently, and at the same time, the cause of decay and dissolution. Hence the Hindu, not altogether without reason, reckons among his gods both Brahma the Creator and S'iva the Destroyer. So we, when the rose withers on its stalk and presently all its petals lie scattered on the ground, cannot but regard its loss as of the nature of evil, although no pain has been incurred. The same remark applies to the fading of the hues of sunset, to the departure of spring and summer with all their attendant glories, and amongst ourselves to the passing away of the bloom and freshness of youth. Beauty gives place to wrinkles, and the vigour of our earlier days to the increasing infirmities of old age.

Destruction sometimes occurs on a much larger scale, as when some wide and fertile tract of land covered with its cornfields and vineyards becomes buried under heaps of volcanic ash, or when a sudden tornado sweeps over a tropical isle carrying everything before it. In the same category we must place fires and floods, earthquakes and raging tempests, each of them bringing desolation in its train. There is here, however, a distinction to be observed

¹ The average speed of a star is said to be about 20 miles per second, whereas that of the electron inside a hydrogen atom is said to be about 1400 miles per second.

between those evils which are the result of purely inorganic forces operating upon things from without, like the ones just mentioned, and those which, as in the withering of the rose and the passing away of youth, are dependent upon forces apparently inherent in, and peculiar to, all forms of organic life.

Altogether, then, as the result of the above analysis, we may classify the various forms in which evil manifests itself as follows, indicating in the second column the different orders of being which they severally affect.

<i>Forms of Evil</i>	<i>Affecting</i>
I. Evil as willed (Moral Evil) :	} Man only.
(1) Overt acts.	
(2) Inner intentions.	} Man and, to a much lesser extent, the higher animals.
II. Evil as endured (Suffering) :	
(1) Mental suffering.	} Man and all animals, except perhaps the lowest.
(2) Physical Suffering :	
(a) Bodily cravings.	
(b) Bodily injuries.	
(c) Diseases.	} Man, animals and plants.
(d) Infirmities of old age.	
III. Evil as contemplated :	} All orders of being.
(1) Result of inherent causes.	
(2) Result of external causes.	

We have next to inquire into the source or sources of evil. Of *Moral Evil* it may be said, that it is the almost inevitable result of our possession of freedom, coupled with the fact that evil, as often as not, presents itself in a guise so very much more attractive than good. If our power of choice were taken away, or if the right were always the easier and more pleasant thing to do, moral evil would in either case cease to be. But the subject is one to which I shall return later.

As to *Suffering*, it is frequently, of course, the result of moral causes. When a man has slandered or robbed or done violence to his neighbour, besides the punishment which he may possibly bring down upon his own head, there is, of course, the pain and loss sustained by the

individual whom he has wronged. And again, there is a very true sense in which it may be said that the sins of the fathers are often visited upon their children. But this raises the question,—Is all suffering to be accounted for in this way? Does it always proceed from a moral cause? It is a question, however, which we should scarcely have asked, if it were not for the opinion once so widely held, and still held perhaps by some, that everything in the nature of suffering is the result of sin, and is ultimately to be traced back to the so-called “Fall of Man,” previous to which it is supposed to have had no existence. Now whatever interpretation, allegoric or otherwise, we may choose to put upon the old Genesis story—a matter which lies altogether outside the scope of the present work—this much at least is certain, that suffering had forced its entrance into our world millions of years before man arrived. Besides those

dragons of the prime
Which tare each other in their slime

TENNYSON.

—a clear reference to the far-off Reptilian age¹—there were those great carnivores which at a somewhat later date began to appear upon the earth. Like the modern representatives of the cat tribe, they were furnished with sharp retractile claws for seizing their prey, and with peculiarly modified teeth known as “carnassials” for cutting up the flesh of their victims. Belonging to them there were those very formidable beasts, the sabre-toothed tigers (*Machairodonts*), whose upper canines were converted for offensive purposes into huge tusks nearly a foot in length. Many other examples of a similar kind might be quoted, all going to show that suffering existed in the world long before Man.

Hence while fully admitting that a great deal of the suffering under which the human race now labours is due to moral causes, I hold that for much of it, and perhaps the larger part, we must seek the cause or causes elsewhere. It is rooted, as I shall now try to show, in the very constitution of things, and is mainly the result of certain great

¹ Chapter XXIV, p. 361.

principles which dominate, and most profoundly affect, all forms of sentient life from the lowest up to Man. Let us see what these principles are and consider them one by one.

I. *The Principle of Dependence upon the Environment.*—This is a principle to which I have already called attention. It means that, in order to maintain themselves alive, all organisms have continually to be drawing upon their environment for certain indispensable things, of which by far the most important are food and free oxygen. They are absolutely necessary, because for the performance of any one of the vital functions energy is always required, and this energy, in the case of animals and men, is wholly derived from the food which they have eaten, and can then only be rendered available by means of a constant supply of oxygen. It will be remembered in this connection how the functions of digestion, respiration and the circulation of the blood, together with all those highly complicated structural arrangements needed for their discharge, are entirely for the sake of providing us with the energy, apart from which we should be unable to lift a finger or stir a step.

Now although the amount of oxygen in the surrounding air is practically inexhaustible and no effort on our part is wanted to obtain it, it is quite otherwise with our food, of which there exists only a limited supply. Moreover, the supply would be far less than it is and wholly insufficient for the world's needs, if Man were dependent to-day upon what Nature spontaneously offers him, or were content with merely following his primitive hunting instincts. Things, however, being as they are, in order to secure the requisite amount of food, he has been compelled—and now for many long centuries past—to bring wide areas of the Earth's surface under cultivation, and to apply himself with unceasing diligence to the task of raising crops of corn and other vegetable produce, besides keeping large herds of sheep and cattle. But all this has meant an enormous expenditure of labour—labour continuously applied with scarcely any relaxation all the year round, and in which at the present time many millions of persons must be

engaged. It is because of this that, whereas we can get all the oxygen we want free of charge, our food, that other great necessary of life, has always in some shape or another to be paid for. Of the extent to which this is the case we can form perhaps some sort of a rough idea from the fact that during a recent year we spent as a nation some £350,000,000 on imported food-stuffs alone. Consider the immense amount of labour which such a sum represents, and consider also the immense amount of it which had to be expended here at home over the manufacture of goods to be sent abroad in exchange for the food received.

There are two other things which are essential to our life and for which we have continually to be drawing upon the environment, viz. water and a sufficient amount of warmth. Water, as a rule, is easily obtainable, except when, as in our big towns and in many of our urban districts, it has to be brought from a distance, which once more necessitates labour and causes it to command a price. Manchester, as we know, gets its supply from Thirlmere, and is now proposing to get it from Hawes Water as well.

The obtaining of a sufficient amount of warmth is a wholly different matter, and involves labour on a much more extensive scale. This is because, to protect ourselves against the cold and the frequent inclemency of the weather, we need not only fuel for our fires, but clothes for our bodies and houses to shelter ourselves in. The list, therefore, would be a very long one, if I were to enumerate all the occupations which are directly and indirectly concerned in supplying us with these necessities. Naturally we think first of the miners upon whose exertions we depend for our coal, and then of the many workers in the various textile industries, and of those who, like the masons, the bricklayers and the carpenters, are employed in the building trade.

The main point, however, in what has just been said is that for the human race to live, and to live in even the most moderate degree of comfort, a prodigious amount of labour has to be bestowed—labour which, although to those persons who are in good health it may sometimes prove pleasurable, is very far from doing so always, and in many cases is felt

to be exceedingly irksome. There is much of weariness of the flesh and of dull monotony often attached to it, nor is it surprising, if at the end of the day many should be glad to fling down their tools. Particularly does this apply to those who are getting past their work, but who are obliged to cling on to it in order to earn their living. Again, there are those who are unable perhaps to obtain work of any sort, and whose minds are full of anxiety, as they think of the future and of what is to become of their wives and little ones.

From all this it must be abundantly clear that much of the suffering, which in one form or another falls to Man's lot, is due to the cause which we have been considering, viz. to that peculiar relation of dependence in which he stands to his environment and which makes so heavy a demand upon his time and labour. How utterly different would life have been, how changed from what it actually is, if our supply of food had been as plentiful as the air we breathe, if we had been in no need of extra warmth and clothing, and if we had been provided with houses already built and furnished! As it is, we find ourselves placed under certain hard and inexorable conditions to which we are compelled to submit, and which in no small degree contribute to the general sum of both physical and mental suffering.

II. *The Principle of Conflict with the Environment.*—We have next to see that the environment, from which with so much toil we are forced to obtain the necessities of life, is by no means always friendly to us, but is at times distinctly hostile. I have referred already to the destruction frequently wrought by earthquakes, volcanic eruptions, storms at sea and so forth, and to the way in which—as for instance in some house at night—a fire may suddenly break out, nobody knows how, and all the inmates, women and little children included, may perish in the flames. The truth is, we are surrounded by a world of forces which pursue their relentless way, quite regardless of how our human feelings and interests may be affected by them. In this, however, there is no suggestion of any malicious agency at work—

far from it—for the falling rock will as soon smash in pieces an earthenware vessel as a human skull, if it should happen to be in the way, or, for the matter of that, strike the ground without doing any damage at all.

Again, it is not only with the inorganic forces of nature that Man has been obliged to contend, but with living beings as well. I need not dwell here upon the long and bitter struggle which in quite primitive times he was compelled to carry on with the various beasts of prey which prowled about his home. Even to-day in tropical climes the tiger and the snake are terrors not altogether unknown, although happily in our own country we stand in no peril from them. As for the wolves, which were once so rampant in our midst, the last are said to have been destroyed during the reign of Henry VII. Unfortunately, however, we have other enemies to our peace of a much more insidious kind, viz. those minute organisms, the microbes of disease, which if once they get a sufficient hold, set up those terrible disorders known as cholera, small-pox, tuberculosis, typhoid and diphtheria. Medical science, as we know, is doing its best to wrestle with them, and there is every reason to hope that it will succeed at last in stamping them out. Meanwhile, every year human lives are being sacrificed in tens of thousands by reason of these dangerous little pests, and it would be hard to say how much of suffering and of mental distress are due to this cause alone.

But Man has had other foes to contend with besides those just mentioned, viz. his fellow-men, who must also be reckoned as forming a part, and a very important part, of his environment. Sometimes, it is true, the struggle has confined itself to mere competition, but, as the pages of history loudly testify, it has again and again, and indeed, quite incessantly, broken out into open warfare. Of this in our own day we have had the most appalling illustration in the great world-tragedy in which we were all involved during the years 1914 to 1918, and from the baneful effects of which we have scarcely recovered yet. But whether the strife of Man with his fellows has been of this fierce sanguinary kind or has assumed the much milder form of

industrial conflict, in either case it has been the source of an immense amount of suffering. There is, however, another cause, a far more fundamental one, which has to be taken into account.

III. *The Principle of Self-seeking.*—This is that deeply implanted principle which is continually urging every organism to direct all its efforts towards its own preservation and towards obtaining whatever may be to its own advantage, quite heedless as a rule of how it may affect others or cause them to suffer. We have obviously to do here with one of those basic facts in connection with Life which, because of its far-reaching consequences, we must steadily keep in view.

It is important to observe that the efforts just referred to are not necessarily *conscious* efforts, for they are exhibited by members of the vegetable, as well as of the animal, kingdom. Thus the roots pushing their way through the soil in search of moisture, the leaves spreading themselves out so as to expose as large a surface as possible to the air and the light of heaven, and the stem by its repeated branchings assisting them in this—are all conspiring together for the maintenance and well-being of the plant as a whole, but quite regardless of everything else. Of course, in the case of the reproductive organs, which in the higher plants are situated in the flowers, it is somewhat different, for they fulfil the double purpose of perpetuating the species and of providing opportunities for the appearance of those fresh variations, apart from which there could be no evolution, no real advance.

Now it is this ever-present self-seeking tendency displayed by all animals and plants alike, this imperious instinct prompting them to give constant preference to the claims of “number one,” which is really at the bottom of all the strife. Even in the vegetable world we can trace how its influence works. Thus the weeds which spring up so plentifully in our gardens are incessantly competing with our less hardy cultivated plants, and would soon win in the unequal contest, if it were not for our timely interference. Again, no one walking through a wood can fail to notice the same

kind of thing taking place. The trees are all seeking to over-top one another in their constant endeavour to obtain the maximum amount of light, with the result that the unsuccessful ones overshadowed by the rest are forced to carry on a very precarious sort of existence.

When we pass up from plants to animals, the self-seeking impulse not only gains in strength, but begins to exhibit certain entirely new features. It gains in strength, because, as we have seen,¹ the amount of food available for animals is very much less than that available for plants, and this naturally tends to render competition considerably more acute. Also, because of their locomotive powers, animals are constantly being brought into close touch with one another, thereby affording increased opportunities for strife. If, like most plants, a lion were always rooted to the same spot, it would obviously be unable to pounce upon its prey.

Far more important, however, is the fact that among animals the self-seeking impulse takes on a distinctly psychical character. It becomes conscious, and assumes the form of a number of cravings or desires, *e.g.* the desire for food, the desire for drink, the desire for sleep and so forth, and it is these desires which are continually driving animals on to action. Further, although these desires when satisfied may produce a certain amount of pleasure, they may, on the other hand, prove a source of much suffering, should they happen to be balked, as is frequently the case. Again, when as between two animals the self-seeking impulse leads to open conflict, it necessarily means loss and pain to whichever of them is vanquished. Hence we see that when to the self-seeking impulse inherent in all organisms certain psychical accompaniments are added, it becomes almost inevitable that suffering should be one of its results.

In the human sphere still further complications arise; but first let me lay emphasis on two somewhat important points.

1. The self-seeking impulse, which when too exclusively

¹ See Chapter IV, p. 42.

followed is the principal cause of moral evil in Man, has clearly been inherited by him from beneath, since it is shared in by all other organisms from the lowest upwards. It is, therefore, through no fault of his that he finds it so deeply engrained in him.

2. In virtue of his superior mental endowments Man has discovered the inner reason or purpose of the self-seeking impulse, and of the various desires in which it manifests itself. He knows, for example, that hunger and thirst and the craving at stated times for sleep have for their real object the maintenance of his own life, and similarly that the sex instinct has for its real object the continuance of the species. But the animals beneath him in the scale simply follow their own desires ; they do so blindly, it never occurring to them that behind their desires Nature has any hidden purpose. Take the bees. In storing up honey against the winter season they are probably quite unaware of the object towards which all their efforts are being directed. Or again, there are the moths and the butterflies which, although they will never live to see their own offspring, are prompted by instinct, as we say, to lay their eggs on or near the particular plants, the leaves of which will furnish the right sort of food for the little caterpillars when they hatch out in the following spring. May it not well be the case then—I throw it out as a suggestion—that Man in following certain of his higher instincts, viz. those moral impulsions to which I shall have to refer in the next chapter, is *really acting in the most reasonable manner possible, although its reasonableness may not at present be always apparent to him*? At present he only very imperfectly apprehends the meaning of these impulsions.

But to resume. Complications of a very serious kind have arisen in the case of Man, owing to the continual *multiplication* of his desires—a multiplication which has been only one of the many results of his superior mental endowments. He has by no means been content with the satisfaction of those primitive instincts which he has inherited from, and still shares with, the brute ; but has sought for satisfaction in all sorts of newly devised ways. Thus in the

course of time, and with the so-called progress of civilisation, he has managed to surround himself with a kind of artificial environment, consisting largely of objects expressly intended to minister to his comfort and delight. Moreover, these objects, constituting what is generally known as wealth, have come to be owned—whether rightly or wrongly, we will not stop to inquire—by individuals, some possessing far more of them and others less. Hence has arisen the constant feud between rich and poor, between employers and employed; and to the same economic cause we must attribute many, if not most, of the wars which have devastated the earth and led to so much bloodshed. Thus within the human sphere it is evident that the occasions for strife have been indefinitely multiplied; and with increased strife there has come about increased suffering.

It is only fair to add to the above that, besides the desire for material possessions, desires of a distinctly higher order have also arisen, such as the desire for knowledge, the desire for beauty, whether revealed in the world around or in works of art, and the desire for goodness—desires for the satisfying of which no one else need be the loser. At the same time it must be admitted that a certain measure of this world's goods is often necessary for their full gratification. At present, unfortunately, one has to pay for a University education, and it costs money to go on a visit to Norway or Switzerland to see some of the grandest aspects of Nature.

IV. *The Evolutionary Principle.*—It is not likely that death *as such* is held in fear by any of the lower animals, but it is certainly otherwise among human beings, although, no doubt, it is dreaded by some far more than by others. Apart, however, from any mental suffering to which such fear may give rise, there is the suffering, generally much more intense, which death inflicts upon others, viz. upon the relatives and friends left behind, and especially when the ties of affection have been exceptionally strong. We think of the grief, almost inconsolable, of the poor widow who has just been bereft of her deeply devoted and perhaps only son. But death, as I pointed out towards the end of

Chapter 1, appears from the first to have been inseparably bound up with the Evolutionary Process. For if Life, starting from quite humble beginnings, was to unfold itself into continually higher forms—which it could only do by means of an immense succession of reproductive acts, thereby affording opportunities for the occurrence of new and progressive variations—Death was practically obliged to be in constant attendance on it, to follow it as its dark shadow. Otherwise the world would not be able to hold, and still less to sustain, the enormous multitude of animals and plants which would by now have accumulated upon its surface—that is, if we suppose that all the living beings which have existed from the earliest geological times had continued down to the present day. Imagine what it would be like, if they were all brought back to life again and suddenly let loose upon the Earth. As it is, the Earth may be regarded as one vast burial-ground of all the generations passed away, the number of individuals now alive upon it forming only an infinitesimal fraction, as compared with those whose remains lie entombed in the rocks.

Hence, as I have said above, death appears from the first to have been inseparably bound up with the Evolutionary Process; and seeing that Man is himself a product of the Evolutionary Process, death appertains to him also. Although he is the highest of God's creatures, he has not been allowed to claim exemption from it; it is one of those many things which he has inherited from the past and from beneath. But death in his case involves, as we have seen, more or less of suffering—suffering which has, therefore, for its ultimate cause the Evolutionary Process.

Putting, then, these various considerations together, the conclusion seems inevitable, that although much of the suffering within the human sphere is due to moral causes, viz. to man's too frequent abuse of his freedom, yet by far the greater part of it has its root in the very nature of things, and more especially in those peculiarly hard conditions to which, along with all other organisms, he has been subjected. Our absolute dependence upon the environment, our more

or less incessant conflict with it, the presence in us of those deeply implanted self-seeking impulses which we share in common with the brute, and lastly, the necessity of death imposed upon us by the Evolutionary Process—all these things combine to make our lot by no means a bed of roses. Yet why should this be the case? Why should God have so constituted the world that such painful consequences should flow from it, whereas if He had only willed otherwise, He might have rendered our life on Earth one long uninterrupted dream of bliss?

And the question becomes all the more insistent, if we admit the cogency of the argument set forth in Chapter XXX—if, for the reasons therein assigned, the conviction has in any measure been thrust home upon us that Man, God's last and highest creature, for whom all the previous ages had been toiling, is necessarily of value to Him, and that, in the case at least of many multitudes of the human race, he is of very great value indeed.

Thus we are brought face to face with the profound mystery as to why, if Man is in very truth precious in the sight of God, he should have been compelled to submit to so harsh a regimen—to be placed in a world in which, although doubtless there is much of happiness to be got, there is also so very much of sorrow and suffering.

It appears to me that, although we may be unable to find any complete solution of the mystery, considerable light may be thrown upon it, as the result of a careful inquiry into the underlying significance of Man's moral nature, as likewise of the fact that in this Universe of ours right and wrong have, as I shall try to show, a certain objective existence.

CHAPTER XXXIII

THE MORAL NATURE OF MAN

It is unnecessary perhaps to say that the problems connected with this subject not only are many and extremely complicated, but have given rise in the past to very great differences of opinion. Hence it would be quite impossible for me in the space at my disposal to discuss them at all thoroughly, even if I were competent to do so.¹ This need not, however, be considered a drawback, seeing that my chief, though not only purpose, in dealing with the subject is to find out to what extent, if any, it may help to cast light on the serious difficulty presented by the existence of evil in the world, and of all the suffering in it more particularly.

There is one important problem which naturally confronts us at the very outset, viz. that of the "Freedom of the Will." Do we, or do we not, possess any real power of choice? It has been contended by many that we do *not*, all our actions being as absolutely predetermined as are the movements, say, of the heavenly bodies; and this—so it is alleged—because we always and inevitably obey whatever may happen to be the strongest motive. By others, however, who take the opposite, and what may be termed perhaps the "common-sense" view, it has been urged, and I think very properly:

1. That the direct testimony of consciousness on this point ought most certainly to be taken into account. For this seems to tell us plainly, in reference to many, if not all, of our actions, that we *might* have acted differently.

2. That if in the sphere of Life no single function or

¹ For further information on the subject the reader may consult J. S. Mill's *Utilitarianism*, Herbert Spencer's *Data of Ethics*, Paulsen's *System of Ethics*, T. H. Green's *Prolegomena to Ethics*, Sidgwick's *Methods of Ethics*, and Martineau's *Types of Ethical Theory*.

minutest structural detail is without its purpose, it is only reasonable to suppose that consciousness must have its purpose too. Under whatever precise circumstances consciousness may at first have arisen, does it not look as though it had been intended—and especially in the case of Man—to exercise some sort of effective control over his actions? Otherwise we should have to regard it as a mere spectator of the onward course of events—events which, although many of them might appear to be guided by what is commonly called the Will, in reality were not so, but were following one another in precisely the same order which they would have done had consciousness been absent.

3. That when we choose the right in preference to the wrong, we are frequently aware of a more or less intense inward struggle. The temptation to disobey the call of duty and to turn aside into some seductive-looking “bypath meadow,” can only in many cases be overcome by the putting forth of a very strong and determined effort. But experiences of this kind seem to indicate that we are no mere puppets in the hands of Fate, but have the control more or less over our own destinies.¹

4. That unless our wills are really free and we are responsible, therefore, for our actions, how are we going to account for those peculiar feelings of satisfaction and of internal harmony which follow upon doing the right? And again, how are we going to account for those other feelings of shame and remorse which are often the result of wrongdoing?

5. That if the freedom of the Will is a pure delusion and all our actions are therefore necessitated, the question may well be asked,—What right have we to pass judgments, whether of approval or disapproval, upon our fellow-men, or to punish for their misdeeds even the worst of criminals?

6. That because in the external world everything appears to obey certain inflexible laws, this gives us no warrant for supposing without further proof that the same holds true in the world of mind. It is doubtful, indeed, as already

¹ See on this, and on the previous point, pp. 133-136.

stated,¹ whether even in the external world the reign of law is quite as rigid as it has sometimes been imagined.

Granting, then, that the Will is free, we have to avoid, on the other hand, the mistake of thinking that in every action we perform this freedom is necessarily being exercised. Many of our actions are manifestly the result of habits previously formed, although doubtless in the formation of them our wills have generally played a part. Again, it must be allowed that in a large number of instances we are determined by what after all is only the strongest motive, and especially is this the case when no moral issue is at stake. In choosing, for example, whether we will spend our holidays in the Isle of Wight or in some more favoured spot abroad, we naturally choose the alternative which, all things considered, offers us the greatest attraction. If, however, to enable us to go abroad, we should be seriously tempted to appropriate money which does not belong to us, then the Will may have to assert itself very energetically before the temptation is dismissed.

But to proceed. Previous to any decision which we may make, whether moral issues are at stake in it or not, there is often a time during which we are mentally turning over the relative desirability of several competing motives, or perhaps, more simply, we are considering whether we shall, or shall not, yield to the pressure of some one motive in particular. This is, of course, the period of deliberation. Having once made up our minds, the next thing we do is to think out the various means to be employed and the successive steps to be taken for the attainment of the desired end; after which we may still have to wait a considerable time before we are able by some decisive act to set the necessary train of events in motion. These events may, or may not, require further intervention on our part; and they may, or may not, present any special attraction for us. Indeed, as often as not, they affect us indifferently, and even if they should cause a certain amount of discomfort or of positive pain, we are willing, as a rule, to put up with them for the sake of the end to be gained. As to the conse-

¹ See Chapter XXX, pp. 455-456.

quences flowing from the entire action, there are generally some which we clearly foresaw, there are others which we did not foresee, and among the latter there may be a few which we might have foreseen had we given the matter sufficient thought. The subjoined table is intended to illustrate what has just been said.

TABLE I

- A.* The Period of Deliberation.
- B.* The Decision.
- C.* The Consideration of the Steps to be taken for attaining the End.
- D.* The Period of Waiting.
- E.* The Initial or Decisive Act.
- F.* The Series of events, or of still further acts, leading up to—
- G.* The Desired End, the previously entertained idea of which formed the Motive.
- H.* The Foreseen Consequences.
- I.* The Unforeseen Consequences, which might nevertheless have been foreseen had sufficient thought been given.
- J.* The Same, but which could not by any possibility have been foreseen.

It must not be supposed, however, that in every case the entire series as given above is necessarily gone through. In acts of sudden violence, for example, or when at any time the passions are strongly aroused, *A*, *C*, *D* and *F* may practically be absent, as also *H*.

The Intention as distinct from the Motive includes all the stages *B* to *G*, whereas the moral responsibility incurred—when moral responsibility is in question—extends certainly from *E* to *I*, and should perhaps take in *B* and *C* as well, although of course there is always the possibility that before *E* is reached the Decision *B* may be recalled.

In reference to our Motives the following points are to be noted :—

1. They may be either of the positive or of the negative kind, according as they are pleasurable or painful. And here for the moment I will adopt the theory—which, as we shall see presently, is open to considerable criticism—viz. that pleasures and pains are the sole motives of human

conduct. Anyhow, it must be admitted that a large part of our activity is directed towards the obtaining of pleasures and the avoidance of pains, the terms "pleasure" and "pain" being understood in a very wide sense, as including, for example, the pleasures and pains associated with our æsthetic emotions. We may say, then, that prospective pleasure always inclines us to a course of action leading to its realisation, or, if the pleasure is already in part realised, to its heightening and continuance; whereas prospective pain inclines us to a course of action which will prevent its realisation, or, if the pain is already in progress, to its extinction, or at all events its mitigation.

2. As motives, our pleasures—and likewise our pains—differ among themselves *quantitatively* according to their (*a*) Intensity, (*b*) Duration, (*c*) Certainty of Realisation, and (*d*) Nearness in Time. These are all points which we more or less consciously take into consideration in deciding on our courses of action.

3. They also differ among themselves *qualitatively*—a point of considerable importance, as we shall see presently. Indeed, on this basis we may classify our pleasures—or to use a more colourless expression, our satisfactions—in a sort of ascending series as follows:—

TABLE II

Classification of our Pleasures or Satisfactions

- A. Bodily, of the passive kind—pleasures of the senses.
- B. Bodily, of the active kind—pleasures of exercise and pursuit.
- C. Intellectual—pleasures of interest, of success in solving problems and in making discoveries.
- D. Æsthetic—delight in Natural Scenery, Poetry, Music, Works of Art.
- E. Social—pleasures of Companionship, Friendship, Love; the Family relations.
- F. Moral and Religious satisfactions.

It is extremely difficult, however, to weigh these different classes of satisfaction over against one another. How are we to estimate, for example, the relative amounts of pleasure to be derived from eating a good meal, from engaging in

some form of manly exercise, from gazing at a glorious Alpine scene, and from enjoying the society of a bosom friend? And a similar difficulty presents itself in connection with the corresponding pains.

4. In addition to the primary motive there are often others of a subsidiary character which may more or less influence our conduct. Thus it sometimes happens that, when the primary motive is of the pleasurable kind, there is another, a painful one, which is connected with some event occurring elsewhere in the series as given on Table I, and which acts as a deterrent. For instance, we may have a strong liking for a particular dish which happens to be on the table, but we may very wisely refrain through fear of consequences.

5. Many of our greatest pleasures are those which come to us when not directly sought. They follow rather upon the healthy discharge of our various bodily and mental activities. But this is a point to which I shall return a little further on.

After these preliminaries we come to the extremely important question as to what it is which really constitutes the right. What do we mean by saying of certain actions that they are morally good, of others that they are morally bad, and of yet a third set that they are morally indifferent? Many and diverse as are the answers which have been given to this question, they may all be arranged perhaps under a few main heads.

I. First, there is the view maintained by many, that in the human mind there resides a special faculty, popularly known as the Conscience, which enables us to distinguish at once between right and wrong, and which at the same time enjoins us to follow the one and eschew the other. There is no need, therefore, to worry ourselves over the consequences of our actions. We have simply to attend to the voice of this inner, this infallible guide. Right is right, because the Conscience commands it.

In connection, however, with this, the so-called Institutional Theory, the objection may be raised, that the deliverances of the Conscience have not always been in accord with one another. They have differed at different

periods in the world's history, they have differed among peoples occupying different levels of culture, and they have differed even in the same person at different times in his life. To meet this objection, it has been suggested that Conscience, like every other faculty we possess, is a thing of growth, and has undergone, and is still undergoing, a process of evolution. Hence in seeking to ascertain the morally right we should pay heed, not to the conscience of the mere individual, but to the collective conscience, so to speak, of the most advanced peoples, and to the consciences more especially of those who have stood out among their fellows as men of the loftiest type. Now although there is a good deal to be said, no doubt, in favour of this suggestion, it does not seem to afford much help to the individual who, suddenly finding himself placed in some hitherto untried situation, wishes to know what is really the right thing for him to do.

Again, there is the further question as to whether, as a matter of fact, the Conscience declares itself afresh every time there is need for coming to a moral decision, or whether it has not rather declared itself once for all in favour of certain generally received maxims—such as “Thou shalt do no murder,” “Thou shalt not commit adultery,” “Thou shalt not steal”—which maxims it simply applies to new cases as from time to time they arise. But this suggests yet another question as to how these maxims, these moral precepts, first originated. Are we to regard them as the crystallised-out results of the deliverances of Conscience at a much earlier stage of civilisation, and which were subsequently enforced, just as they are being enforced to-day, by certain legal and social sanctions? Or did the legal and social sanctions come first, and so give rise to the moral maxims?

And here I may remark, that there come times when the purely Intuitionist Theory apparently breaks down and, when to arrive at a true moral judgment, we are compelled to take into consideration the consequences of our actions. It sometimes happens, indeed, that in order to do what we believe is right, we have deliberately to set aside one

or other of the generally received maxims—in fact, entirely to ignore it. Thus, although in ninety-nine cases out of a hundred it may be our duty to speak the truth, yet, if in some remote spot we were attacked by a gang of robbers and asked to state where a certain individual lived or could be found, we—knowing it to be their full intention to go by night and murder him, and probably his whole family as well—should be perfectly justified in giving them the lie direct. Perhaps it may be said that even in such a case it would still be the Conscience which had decided the point. Possibly so, and yet surely not by any act of pure intuition, but as the result rather of reflection on the terrible nature of the *consequences* which would have followed had we spoken the truth. But if in such an exceptional instance the consequences have to be taken into account in order to form a correct moral judgment, may it not well be the case, that the rightness or wrongness of all our actions is to be determined in the last resort by the application of the same principle? Hence among other things it would follow, not that an action is right because the Conscience commands it, but rather that the Conscience commands it because it is in itself and, therefore, objectively right.

II. Granting, then, that the moral character of any action depends upon its consequences, viz. upon whether they are good or bad, the next question is,—What are we to understand in this connection by the terms “good” and “bad”? Or we may ask,—What is the nature of that “good” which in all our actions we ought to be striving after? To this it has been replied that, inasmuch as happiness in one form or another is the only end after which—so it is alleged—human beings do *actually* strive, it follows that happiness must be that good, and that the moral character of any action must, therefore, be judged by the amount of happiness which it tends to produce—the happiness, that is, not only of the agent himself, but of all others whom his action may in any way affect. This theory of what at bottom constitutes the right is usually known by the somewhat misleading title of “Utilitarianism,” and is often referred to as the “Greatest

Happiness Principle.” It has obtained very wide currency ever since the days of Jeremy Bentham (1748–1832), and has been upheld, although with sundry modifications, by a number of later writers, such as John Stuart Mill, Alexander Bain and Herbert Spencer.

Now whatever may be said of this theory by way of criticism, it at least possesses the merit that, unlike the purely egoistic one generally associated with the name of Hobbes (1588–1679), it insists upon taking into full account the bearing of our actions upon others. It is essentially altruistic; right conduct is that which tends to promote not only our own happiness, but that of our fellows. At the same time it presents certain serious difficulties which may well make us hesitate before accepting it.

1. And first, it is often far from easy, in reference to any contemplated line of action, to form even a tolerably correct idea beforehand of the amount of happiness which it is likely to produce, and especially if, as is generally assumed, happiness is to be measured by the preponderance in human life of pleasures over pains. Who is to provide us with the pair of scales in which to weigh these two, the one against the other?

2. The difficulty in question is enormously increased by the circumstance already alluded to that pleasures and pains differ among themselves not only quantitatively, but qualitatively. This renders the process of “weighing” almost impossible.

3. It is further increased by the circumstance that what one individual may regard as the highest form of pleasure—that which above everything else he considers essential to his happiness—another may regard with almost complete indifference. A Sir John Falstaff addicted all the day long to the consumption of sack would not be likely to find much pleasure in philosophical contemplation.

4. Again, how is the happiness which is supposed to be the end of all right conduct to be parcelled out? Am I to act in such a manner, as that just the few shall greatly benefit by it, or that the many shall benefit by it, although each only to a slight extent? There is nothing in the

“Greatest Happiness Principle” to give guidance in this matter.

5. Further, what is to be my own share in the general happiness? How much of it may I justly claim? May I claim any? Obviously we are presented here with another knotty problem.

6. Lastly, it is not difficult to imagine cases in which the Utilitarian theory might condone acts universally condemned. A poor clerk, for example, burdened with a large family and having his wife dangerously ill and greatly in need of the best medical advice, is quite unable to pay the fee which would be asked by a big London physician. He says to himself, however,—“My employer is a man of unlimited means, and can quite readily afford, therefore, the needed sum. Moreover, I know a way by which I can get it from him without the secret ever being disclosed.” Accordingly he purloins the money, the big London physician comes down and tenders his advice, the wife speedily recovers, and the dark cloud of anxiety which for several weeks has been hanging over that little home is entirely dispelled. Now on the Utilitarian theory with its “Greatest Happiness Principle” it would be extremely hard to say why the act should be considered wrong; and yet it would unquestionably be condemned by the general verdict of mankind, and there would be but little hesitation in branding the man as a thief.

III. Let us look now into the whole subject a little more closely. We have already seen that our pleasures and our pains differ from one another so widely in character, that it is often wholly impossible to form any sort of quantitative estimate of them. Not only so, but we instinctively recognise that there are several grades among them, some occupying a much higher level than the rest. Thus the intellectual and social pleasures are felt to be of a far nobler kind than those which result from the satisfaction of our merely bodily senses. Still nobler are the pleasures, if they may be described as such, which follow upon the honourable discharge of our duties towards our fellows, and upon the performance of acts of kindness and forbearance.

Whether or not in this connection we are right in using the word "instinctively" does not really matter. The fact remains that we do somehow draw the distinctions referred to. And that we are fully warranted in doing so would appear from the following considerations:—

1. The lower, the merely sensuous pleasures are those which we share in common with the brute. The higher ones are those which for the most part are peculiar to us as human beings—to beings, that is, who, in fulfilment of the Divine plan and purpose, are the latest and apparently the final products of the Evolutionary Process. But as before remarked, that which comes last is presumably of greater value than that which preceded it.¹

2. The distinctively human pleasures are the least self-contained, the least selfish. We can enjoy them without detracting from the pleasure and general happiness of others. Pre-eminently does this apply to the pursuit of the three great ideal ends—Truth, Beauty and Goodness—of which the merely animal creation knows practically nothing.

3. The higher pleasures, although they may lack the peculiar keenness and intensity of the lower ones—which are apt at times to become exceedingly importunate—are distinguished from the others by their permanent quality. In this respect they contrast strongly with the fleeting character of our bodily satisfactions.

4. The life which is given up to merely sensuous enjoyment, as in the case of the libertine, the confirmed drunkard and the mere epicure, is one which by the dispassionate onlooker is invariably despised, whereas we all delight to honour the man who at the opposite extreme finds his highest satisfaction in the endeavour to benefit his fellows and to do always the right thing, although it may often mean considerable personal sacrifice.

5. Again, suppose it were possible to manufacture a drug which like opium would be capable of producing the most exquisite bodily sensations without causing any of its deleterious effects, and suppose it could be produced so cheaply and in such large quantities that everyone, even

¹ See Chapter XXXI, p. 477.

the poorest, could take his fill of it, what should we think of the human race if it abandoned itself entirely to so degrading a form of self-indulgence, and ceased any longer to find delight in anything of a more elevated nature? We may well call to mind here that saying of Mill's, that it is better to be a "dissatisfied human being than a satisfied pig."

From the above considerations we might be led perhaps to adopt a theory of what at bottom constitutes the right not very far removed from that of ordinary Utilitarianism. The difference, of course, would be, that the happiness aimed at would be a happiness in which the higher satisfactions were given precedence over the lower ones, the virtuous, the truly ideal, life being that in which *all* the various satisfactions had been brought into harmonious relations to one another, each having been assigned a place according to its intrinsic worth.

At this point, however, we have to consider whether after all mere happiness—even happiness of the most refined type—is the true, the Divinely intended goal of human conduct, so that actions are to be deemed right according as they tend to promote it. May it not be, that the various satisfactions which go to make up happiness are means rather to certain important although often very imperfectly understood ends? Even in the case of the lower pleasures, those which result from the gratification of the purely bodily desires—such as hunger, the craving for rest and the sex instinct—is it not plain that each is designed to serve a purpose outside of and beyond itself—either the maintenance of the life of the individual organism, or the continuance of the species to which it belongs? These pleasures exist both in animals and in ourselves, not for their own sakes, but as forming kind of finger-posts for the guidance of certain fundamental activities.¹ Hence it is not unreasonable to suppose that the same principle applies, and perhaps with greater force, to all the higher, the specifically human satisfactions. It would be a mistake to regard even them as so many ends in themselves. Of this we seem to

¹ See Supplementary Note at end of this chapter.

be certified in other ways. Although it may be a truism to say so, in the pursuit of knowledge, it is knowledge surely which is the thing pursued, not the mere pleasure which the pursuit often brings with it. Similarly with the man sincerely virtuous, he endeavours to live the moral life for its own sake, not because he is moved to it by any thought of the inward satisfaction which it is likely to yield him.

Our final conclusion, then, would appear to be this : that right actions are those which tend to further the healthy and harmonious development of all our various faculties and powers, and especially of those higher ones which are most characteristically human—for surely that is what God must have intended by conferring them upon us. Moreover, seeing that we are by Divine appointment not isolated individuals, but social beings, placed in all sorts of relations to one another in the family, amongst our immediate neighbours and as members of the State, our actions must be such as will at the same time further a similar development in them. By such a course true happiness, and of an abiding quality, is most likely to be found ; but it will come to us as a kind of side gift, not because we have directly sought after it.

Look at some full-grown, well-proportioned tree. Its perfection consists in the complete harmony of its several parts. It is not all roots, or a mere entanglement of barren branches, or a mass of leaves and blossoms only. All these different organs so needful to its life have been properly developed and in their right mutual relations to one another. So also must it be in human life, if it is to attain to anything like ideal perfection. There must be no defects, no excrescences in it ; there must be no pampering of just one side of it at the expense of the rest, no starving of the soul for the sake of the body, or of the body for the sake of the soul, but a complete equipoise of the various faculties and powers, so that they may blend into one consistent and concordant whole.

Man's highest good, we may say, then, consists in this : his continual growth into all that which as a man he was intended to be, instead of the concentration of his energies,

as is too often the case, upon just the obtaining of a succession of transient pleasures, and upon the amassing of wealth, of which the chief use afterwards is to be the obtaining of further pleasures of the same kind. If we ask,—“Who is the individual whom we most admire and reverence and in our better moments would fain copy?” the answer is at once ready. It is most certainly not the man who has spent all his days in sucking life’s orange, and who will be forgotten as soon as the clods have settled down over his grave, but the man rather who has been living the all-round and vigorous life, public spirited, helpful to others, and both seeking and finding his own good in the good of the social community to which he belongs.

IV. But although right may be right on purely objective grounds—because of certain consequences which flow from the doing of it, certain noble ends which are to be gained by it—it may, nevertheless, be true that we possess a “something within,” which both enables us to discern the right and at the same time urges, or rather commands, us to follow it.¹ Light seems to supply us here with a good illustration, for although it exists in the world outside in the form of ethereal vibrations, it can only reveal itself to consciousness by means of a bodily organ specially adapted to receive it. Conscience, accordingly—that “something within”—may be regarded as standing in much the same sort of relation to what is objectively right, as the eye stands to the ethereal vibrations. Just as the eye, too, is an extremely complex organ, and has only reached its present perfection at the end of a prolonged course of Evolution, so the Conscience, psychologically considered, may be equally complex and, as already remarked, may have undergone, and may still be undergoing, an Evolution of a corresponding kind. That something of this sort has really happened is evidenced by the fact that practices like infanticide, slavery and the burning of witches, which in former days passed unchallenged, are now viewed with abhorrence by all the more civilised peoples.

Further, and as bearing out what has been said above,

¹ Kant’s *Categorical Imperative*.

to whatever extent in primitive times men may have endeavoured to do what they conceived to be right, it was not because of any abstract notion which they had formed of the nature of right, but because they were prompted thereto by certain higher impulsions, viz. those which we include under the term "Conscience." They did not reason within themselves, "If we pursue such and such lines of conduct, we shall be promoting the all-round and harmonious development of ourselves and of our fellows," but, like numbers of good and honest folk living at the present day, they simply followed those higher impulsions without stopping to inquire into their *raison d'être*.

An animal, as we have seen,¹ roams about in search of food, not because it is consciously striving by this means to maintain its own existence, but because it is driven to do so by the imperious instinct of hunger. In the same way it is driven by other instincts to perform a multitude of other acts, the meaning and purpose of which it does not comprehend, but which have their meaning and purpose nevertheless. Similarly, primitive man was in much the same predicament. Until his intelligence had reached a certain level, he remained equally ignorant as to the inner reason of his many and very varied instincts. Only very gradually could he have risen to a true understanding of them.

But now—and here we approach a most important subject—over and beyond those purely animal instincts or impulsions like hunger, sex and so forth which Man had inherited from the brute life beneath him, there began to come in those higher impulsions which were to give the start, so to speak, to his moral development. And yet the meaning and purpose of these, he could no more at first understand, than the animal had been able to understand the meaning and purpose of hunger. All that he was conscious of was a certain inward pressure urging him to do the right; but the idea never occurred to him that, by yielding to this pressure, he was forwarding his own higher development, and along with it the higher development of mankind in general.²

¹ See Chapter IV, p. 43.

² See the previous chapter, p. 490.

Now we may regard the emergence in man of these higher impulses as having marked the commencement of an altogether new era in the Evolutionary Process. And coming, as they did, on the top, we may say, of the old and merely self-seeking impulses, what did they immediately tend to bring about? Nothing short of this: a state of perpetual conflict which was henceforth to be waged in the interior recesses of man's spirit between the higher and the lower tendencies of his nature. On the one hand there were all the purely animal instincts and desires clamouring loudly for their satisfaction, and on the other hand there was that mysterious Voice within which said,—“Follow instead the nobler path which I am now pointing out to you—the path of Duty and of Right.”

As to the meaning and possible Divine intention of the strange conflict thus set up in the very citadel of man's being, and of the way in which it may help to cast light on the great problem of the existence of evil—these are matters to which I propose to return in the following chapter.

SUPPLEMENTARY NOTE

Paulsen says in his *System of Ethics*, p. 267: “The biologist, therefore, will not regard pleasure as the absolute end of Life, but will consider both pleasure and pain as means of guiding the Will. In the feeling of pleasure the Will becomes conscious of the furtherance of life by the exercise of a function. Hence pleasure is not a good in itself, but a sign that good is being realised.”

CHAPTER XXXIV

THE DIVINE PURPOSE AND THE MYSTERY OF SUFFERING

It may be as well perhaps before proceeding further to summarise very briefly the conclusions which were reached in the preceding chapter. They were as follows :—

1. Actions are right not because they are such as the so-called Conscience approves of, but because they are right in themselves ; they are to be judged by an objective standard.

2. This objective standard is not supplied by the “ Greatest Happiness Principle,” partly because of those marked qualitative differences existing among our pleasures and pains which render it so very difficult to balance them up, and partly because it is extremely doubtful whether happiness—happiness, that is, as generally understood—is after all the true and Divinely appointed end of human conduct.

3. Right actions are rather those which tend to promote man’s Highest Good, this being taken to mean the all-round and harmonious development of his many-sided nature, the lower sides always being subordinated to the higher ones. And among the latter the social side must be reckoned as by far the most important, seeing that Man can only attain to his true self in and through his relations to his fellows, his own Highest Good, if he but knew it, being inseparably bound up with theirs.

4. The Conscience, nevertheless, has its own special function to fulfil. Whatever account may be given of it psychologically, it appears as a kind of internal sense, enabling us to perceive what is objectively right. It seems, indeed, to stand to the right in much the same sort of relation as the eye and the ear do to light and sound respec-

tively. Moreover, like the eye and the ear, it has been gradually evolved—a process which is very far from being yet complete. Like them, too, it is liable to disease and atrophy.

5. The Conscience not only perceives the right ; it bids us do it. Its commands seem invested with quite peculiar authority.

6. This has given rise in Man to an internal conflict of a unique kind, which is incessantly being waged between those lower instincts and impulses which he has inherited from beneath, and those higher instincts and impulses which may be described as moral.

The exceedingly important question, therefore, has now to be considered, as to what may be the true meaning of this conflict—if we are correct, that is, in supposing it to have any meaning at all. Are we to regard it in the light simply of a calamity in which somehow and most unhappily the human race has become involved, or may we put upon it an altogether different interpretation ?

Now the point, more particularly to be noted here, is that the said lower instincts and impulses, transmitted to us from the past, must be traced back in the last resort to the Will of the Almighty Himself. This may be inferred not only from the fact that the Self-seeking Principle has been most deeply implanted in all organisms whatsoever, so that each is continually striving after just its own advantage, but from the fact that this must have been the case from the very beginning, during those well-nigh interminable ages before Man arrived. Again, seeing that the Self-seeking Principle has been allowed to survive in Man in all its pristine strength, we are constrained to believe that this also must have been in accordance with the Will of God.

It amounts then to this : that *both* sets of impulses, the lower as well as the higher ones, are of Divine origin ; and hence the inevitable conclusion would seem to be, that it was part of the deliberate Divine intention that the conflict above referred to should be fought out in Man. He was to form the battleground, so to speak, on which these two sets of antagonistic forces were to join issue. But why was this

so ordained? Surely there must have been some great underlying purpose in it, if we can but discover what it was.

In the endeavour to do so, it is to be observed, as we shall see presently, that although Man was not compelled to follow the higher impulsions, there are very good grounds for believing it to have been the Will of God that he should. Hitherto, if we allow for certain possible exceptions,¹ all the earlier evolutionary stages had followed one another in accordance with the Divine plan, as determined upon from the beginning. But now there was to come about a change. For the realisation of the final and, therefore, most important stage of all, Man was to be called upon to co-operate; and that this might be of moral value, it was necessary that he should be given the power of choice and certain markedly opposed alternatives between which to choose. These alternatives, need it be said, are those already referred to as the higher and the lower impulsions. And that it was the Will of God that Man should choose the higher in preference to the lower seems evident from the reasons which I am about to give. I must ask the reader, however, to excuse in what follows a certain amount of repetition, as the points to be mentioned are much the same as those set forth in the preceding chapter, though for another purpose. The reasons, then, are these:

1. The Higher Impulsions are instinctively felt to be the higher, whereas most of the Lower ones we share in common with the brute.

2. They appear possessed of commanding authority.

3. By obeying them we become aware of a unique sense of inward harmony. Our life seems enriched and ennobled thereby.

4. By disobeying them the results are the reverse: lack of harmony, and a feeling that we have somehow lowered ourselves in the scale of being. A sense of shame creeps over us, and sometimes of bitter remorse.

5. We judge of our fellows, we form high or low opinions of them, according as they have, or have not, obeyed these moral impulsions. Especially do we applaud all actions of

¹ Referred to later on in this chapter.

a heroic and self-sacrificing kind. Actions, on the contrary, which are mean and purely selfish, and in which the feelings of others have been ignored and trampled on, we unhesitatingly condemn. And these remarks apply to the judgments which we form not only of those whom we meet in real life and have read about in history, but of the various characters portrayed in fiction and the drama. Contrast, for instance, our detestation of such monsters in human form as Goneril and Regan, with the very different sentiments which we entertain towards Cordelia and the loyal and honest-hearted Kent in the same play.

6. Once more, there is the very weighty consideration that the moral impulsions date from a comparatively recent period. They mark an unquestionably late stage in the evolutionary order. They have been superinduced, so to speak, upon the far earlier self-seeking ones, for the origin of which we must go back to distant geological times. But each new stage, as it has been reached, has been presumably of higher value than those which preceded it,¹ and has presumably also disclosed in still clearer outline what we may rightly regard as the ultimate Divine purpose. Hence combined with the other reasons stated above, these moral impulsions may be taken as indicating to Man his true line of advance, the path which it is the Will of God that he should henceforth pursue.

Why, then, has Man so frequently not pursued it? What in so many instances has made him turn aside from it altogether? The answer is not far to seek. It is because of the peculiar vividness and intensity of the self-seeking impulsions, the alluring character of the satisfactions which they have held out to him, and the extreme difficulty which he has frequently felt in the endeavour to break their spell. Hence to achieve a moral victory has been by no means always an easy task, but has often required a strong effort of the will, combined with a readiness to undergo, if need be, a considerable amount of suffering. And it is precisely this element of suffering consequent upon obedience to the higher call, which is the all-significant thing. For what

¹ See Chapters XXIX and XXX.

if the Almighty expressly intended it to be so ! And what if it should be the case that *suffering is always more or less bound up with moral action, if moral action is to possess any real worth!*

Consider, in this connection, how completely our judgment is reversed directly we learn of a good deed—good in itself, and for which perhaps much praise has been bestowed—that it was prompted by purely selfish motives, just to win the approbation of others or to act merely as a salve to conscience. So soon as we discover that it cost the doer of it nothing, but rather brought grist to his own mill, how from that instant does all the glamour which may have surrounded it disappear ! For the same reason there is no kind of merit in abstaining from any forbidden act, if our only motive for doing so is simply the fear of punishment or the loss of the good opinion of our fellow-men.¹

To repeat in another form what has been said above—that the choice in Man between the two sets of alternatives might be of real value, it was essential that those purely self-seeking tendencies and desires, which he had inherited from the brute, should remain powerfully operative in him, in order that, when the Voice of Duty directed otherwise, it might cost him something to set them definitely aside, in response to what he inwardly perceived to be the higher good. In a world in which there had been no sacrifice, no suffering, nothing that was really hard to do, and in which the paths of right and of self-seeking had invariably coincided, moral excellence would have been unattainable. But it was precisely moral excellence, with all that it includes—not mere happiness consisting of an unbroken series of pleasurable experiences—which was ordained by God, so I take it, to be the highest end of human endeavour.

Then welcome each rebuff
That turns earth's smoothness rough,
Each sting that bids, nor sit nor stand, but go !

¹ Sidgwick says: "We certainly think virtue has been manifested in a higher degree in just or veracious conduct, when the agent had strong temptations to be unjust or unveracious."—*Methods of Ethics*, p. 222.

Be our joys three parts pain !
Strive, and hold cheap the strain ;
Learn, nor account the pang ; dare, never grudge the
throe !

BROWNING.

To illustrate the principle still further, let us take the universally extolled virtue of courage. Our first and most natural impulse in the face of danger is to run away from it—the same feeling which at times perhaps comes over the good soldier on the eve of battle, tempting him either to desert the ranks or to keep himself on the morrow well out of the range of fire. But the good soldier will know how to resist the temptation. He will put away all thought of his own safety, and will be ready to plunge into the thickest of the fray, prepared, if need be, to lay down his life for king and country and for loved ones left at home. And it is just this his willingness to sacrifice himself, to endure pain and hardship and to encounter possibly death itself, which marks his conduct as meritorious and which, when the battle is over, wins for him the honour and esteem of his fellow-men.

Or take the totally different, the distinctively Christian, virtue displayed by one who shows readiness to forgive those who have done him wrong. But why should it be accounted praiseworthy ? For no other reason, than that it costs something, it always being so very much easier to cherish feelings of anger and resentment than to tread them down and to treat the past as though it had never been. If it were as simple a thing to forgive one's enemy as to love one's dearest friend, it would still be right to exercise such forgiveness ; but in that case the forgiveness would be of very little merit. For merit consists not in the mere doing of the right, but in the doing of the right when it is hard to do it, when it involves sacrifice, when it contains that all-essential ingredient, pain.

Thus we seem at last to have come within sight of the reason why suffering has had a certain definite place allotted to it in our world. It is because apart from suffering no moral act, however good and commendable in itself, can

possess any real worth, and because it is only by means of a succession of acts possessing such worth that truly noble characters can gradually be built up. Now if the building up of truly noble characters should be, as I believe, God's supreme, though not necessarily His only, purpose on this earth, then a gleam of light does at last begin to break on this exceedingly difficult subject, viz. the Mystery of Suffering.

But at this point I can imagine someone saying,—“Such suffering as that just alluded to can form but a very small fraction of the total amount of it in the world, and it is of this that we need some really satisfactory explanation, if the ways of God to men are to be justified.”

In the endeavour to deal with this objection, our best plan, I think, will be to turn attention once more to those great Principles wrought into the very constitution of things by God Himself, and which, as I pointed out in Chapter XXXII, are the prime causes of suffering. They are as follows :—

- I. Our Dependence on the Environment.
- II. Our Conflict with the Environment—
 - (a) With our fellow-men ;
 - (b) With certain inferior forms of life ; and
 - (c) With purely inanimate forces.
- III. The Self-seeking Principle.
- IV. The Evolutionary Principle.

Let us take these up in turn, although not exactly in the same order as that just given.

And, first, the Self-seeking Principle. Here it must be evident, as already explained, that if at Man's first coming those inherited tendencies had been uprooted in him which are mainly the cause of his so often pursuing his own profit and pleasure to the exclusion of everything else, then that inner spiritual struggle would never have been begun, whereby alone his actions could acquire moral value. Hence, with that all-important end in view, it was necessary that the Self-seeking Principle, so deeply engrained in all

the lower forms of life, should be perpetuated in him and never be allowed entirely to relax its hold.

Next, let us consider the conflict in which Man is always more or less engaged with his fellows, and which in various ways is clearly responsible for an immense amount of suffering. Now although it is the Self-seeking Principle which is, of course, at the bottom of this, obviously there would be no conflict at all if, like so many Robinson Crusoes, each of us had been planted down upon some lonely isle, where neither for good, nor for ill, our actions could affect others. But not only has Providence arranged matters quite differently, so that we are constantly being brought into all sorts of social relations with our fellows, but it is difficult to see how, apart from such an arrangement, moral development would have been possible. For after all, in the vast majority of cases what distinguishes the right action from the wrong one is, that the former promotes the well-being of our neighbours, whereas the latter detracts from it, causing them pain and misery instead. But if it were impossible to cause pain and misery to others, our opportunities for exercising moral choice would become practically non-existent, and our actions, though quite blameless, would cease to have any merit.¹ To the above I may add that it has only been in and through his very varied relations with his fellows, that Man has been able to reach the highest levels of all, and to exhibit in his life those special graces on which Christianity has laid so much stress, viz. patience, pity, forbearance, generosity, and the charity which sums up in itself all the other virtues.

To be perfectly frank, however, I do not think that the considerations advanced above get rid of the entire difficulty, and especially when we reflect on some of the unspeakable cruelties which have been perpetrated by men in the past, as in the persecution of the Christians under Nero and the

¹ "There would be something almost terrible if each of us held his power of happiness untouched, untouchable by any other man. . . . It would be almost a world of chartered selfishness. Why should I think of any one except myself if, no matter what I do, I cannot hurt that happiness which my brother carries shut away in the safe precincts of his own life?" —Bishop Phillips Brooks.

other early Roman emperors, and in the tortures to which many were subjected in the days of the Inquisition. But it may well be the case that grievous wrongs such as these will receive some kind of adequate compensation hereafter if, as we shall see in our last chapter, there are solid grounds for believing in a life beyond the grave. Apart, however, from considerations of this kind, we may still, I think, hold that the power permitted to man of inflicting suffering upon his fellows, is somehow necessarily bound up with that great moral purpose which throughout the ages God must always have had in view.

Coming now to our Dependence upon the Environment, which is undoubtedly, though to a less degree, another cause of suffering, the Principle is one which applies not only to ourselves, but to all other forms of life without exception. Our ability to perform any external action is entirely dependent on the discharge of those very important bodily functions described in Chapters VI, VII and VIII; and these in their turn are dependent on a number of things which are constantly being supplied to us by the environment. Chief among them, of course, are food and free oxygen. Now although, as already explained, it requires no effort on our part to get hold of the oxygen, it is quite otherwise with the food.¹ To secure a sufficient quantity of it, as well as to provide ourselves with those many other things which we consider needful to our life and comfort, an enormous amount of labour has to be expended—labour which often entails much severe toil and hardship upon those engaged in it. But, as before remarked, how entirely would the outward aspect of human affairs be changed, if all our wants were gratuitously supplied—brought, so to speak, to our very doors—and we were never obliged to exert the slightest effort! Under such circumstances what would there be to stimulate and call forth our hidden powers, or to prevent us from sinking back into a merely vegetable sort of existence? As it is, the conditions of our life have been so arranged as to spur us on to almost endless forms of activity, and this, so I take it, because it is only by means

¹ See Chapters IV and XXXII.

of our activities, and the power entrusted to us of choosing whether we will direct them towards good or evil ends, that moral development can be effected.

I said at the beginning of Chapter XXX that it was possible to conceive of the world as having been brought into existence perfect from the very first, so that no subsequent changes in it would have been necessary. But we can now perhaps understand why the world was not made perfect from the first, and why it had to pass through some such process as Evolution in which changes were incessantly taking place. For in a world in which there had been no changes, no actions of any kind would have been possible, and therefore, *a fortiori*, no actions possessed of moral worth. Further, inasmuch as all our actions are performed by means of the energy conveyed to us in our food, and this has ultimately been derived from the energy which was once locked up in the solar beams, we see how even the energy laws of the Universe are not without a certain bearing upon moral ends. It must also, I think, have been with some such reference to moral ends that at a very early stage in the Earth's history the distinction arose between plants and animals. Plants were henceforth to play the comparatively passive rôle of storing up the energy received from the sun, so that animals, destined to be the real actors in life's drama, might have an ever-ready source on which to draw for the execution of their many and very varied movements. And this, which applies to animals in general, applies equally of course to ourselves. We could perform no single act, not even to the lifting of a finger, apart from that remarkable relation established millions of years ago between the two great organic kingdoms.

I see in part
That all, as in some piece of art,
Is toil coöperant to an end.

TENNYSON.

As to our Conflict with the inanimate forces of Nature, it plainly proceeds from the circumstance, that in the purely inanimate sphere we are confronted with a practically

inflexible order of things which has been constituted once for all. A flash of lightning will not turn aside because a human being happens to be in its path, neither will a storm at sea cease to rage to save a passing vessel from destruction. But although from time to time incidents like these occur, in accordance with what is generally known as the "Uniformity of Nature"—which is only another name for the uniformity of God's way of working in the domain of the non-living—there is a certain aspect of the question which we are apt perhaps to ignore. In many, if not most, of the things which we seek to accomplish, what we do is, by some single act, to set in motion a train of causes and effects, which we have reason to believe will eventually bring about the desired end. But this belief is only part and parcel of our general belief in the constancy of the established order—a belief which would immediately be destroyed if things everywhere began to behave in a wholly irregular manner, so that we could no longer put any reliance on them, or form the remotest idea of what was going to happen next. If, for example, after lighting a fire we presently discovered that for no assignable reason the fuel refused to burn, or that the iron of the grate was beginning to melt, or that the heat produced failed to radiate into the room, we should certainly feel considerable bewilderment. And this might well lead on to complete paralysis of all our activities, if from that time forward we found that the entire order of things, to which we had been accustomed, had been upset and that chaos reigned instead. Hence although the seemingly immutable laws which prevail in the inorganic world may occasionally work us pain and loss, they are at all other times of incalculable service to us. Apart from them and the implicit confidence which their steadfastness inspires, we should be unable to carry out any of our purposes, and we should probably abstain from every kind of action, because entirely ignorant of what might be the result. But actions, as we have seen, on account of the multiplicity of the ends both good and evil to which we can direct them, are essential to us as moral beings.

In reference to this whole question of our Conflict with

the Environment and the sufferings which it entails, there is a fine passage in Paulsen's *System of Ethics* (p. 260) which may be appropriately inserted here. He says: "A life absolutely free from pain and fear would, so long as we are what we are, soon become insipid and intolerable. For if the causes of pain were eliminated, life would be devoid of all danger, conflict and failure; exertion and struggle, the love of adventure, the longing for battle, the triumph of victory—all would be gone. Life would be pure satisfaction without obstacles, success without resistance. We should grow as tired of all this, as we do of a game which we know we are going to win. What chess-player would be willing to play with an opponent whom he knows he will beat? What hunter would enjoy a chase in which he had a chance to shoot at every step he took, and every shot was bound to hit? Difficulty and failure are as necessary in a game, if it is to interest and satisfy us, as good luck and victory."

A much more formidable difficulty than any yet discussed arises out of the conflict into which we are sometimes brought with certain of the inferior forms of life. It has been shown that many of our most virulent diseases are due to this cause. Thus cholera, typhoid, diphtheria, tetanus and leprosy are all the result of the invasion of our system by various kinds of those minute and exceedingly low-down organisms known as bacteria. Other diseases, such as malaria, for example, are the result of a similar invasion by organisms not very much higher up. We have to reckon, too, with parasites, which like the tapeworm fastens itself on by its hooks to the inside of the wall of the intestine, or which like the liver-fluke infests the bile ducts of the sheep and of other domesticated animals, although it seldom attacks men.

That the lower forms of life should sometimes be sacrificed for the sake of the higher, need not greatly disturb our faith in the beneficence of the Supreme Power, but when the reverse of this takes place, it is undoubtedly a matter which gives rise to serious misgivings. Why should Man, God's noblest work, be allowed to become the prey

of all these inferior organisms? It is an extremely puzzling question, and one on which I can only offer a few tentative remarks.

And, first, it is a fact, I think, which deserves attention, that many of these parasitical forms show obvious signs of deterioration, and that they are probably descended, therefore, from forms which were considerably higher up. There are a number of instances in which a parasite, although in its youthful condition it may possess organs of sense and organs of locomotion, loses them both when it gets inside the body of its host, the liver-fluke mentioned above being an example in point. There is, for example, the *Sacculina*, which Professor Dendy describes in his *Outlines of Evolutionary Biology* (p. 401) as "swimming vigorously about in its earlier stages by means of well-developed appendages," but which afterwards fixes itself to the under surface of a crab and becomes "reduced to the condition of an irregularly shaped bag." The same author refers to "the conspicuous degeneration undergone by the great majority of parasites"; and Professor J. Arthur Thomson in his *Outlines of Zoology* (p. 163) writes to the same effect.

It would seem, then, that although Evolution as a whole and in all its broader aspects has been continually pressing upwards until at last it has culminated in Man, there has been here and there a certain sinister influence at work which has been continually endeavouring to drag it down. I would suggest, therefore, but with considerable diffidence, that this influence proceeds not from the Almighty, but rather from some invisible power or powers which are hostile to Him and would fain ruin His work. Granting that human beings are able to survive death and to pass, therefore, into some sort of unseen disembodied state, there can be no inherent reason why there should not be other beings, also unseen, who are of a distinctly malevolent kind, and who at certain points in the ever-upward evolutionary movement have intervened and tried to render it retrogressive instead. If that should be the case, then in our fight against these parasites, which in so many instances

have been shown to be the causes of disease, we are not fighting against God, but on the contrary upon His side. The sinister influence, however, whatever may be its real nature, has only succeeded up to a very limited extent, and has completely failed to stay the onward progress of events. Life has gone on unfolding itself in ever fresh and more beautiful forms; and that God really reigns in His Universe is sufficiently attested by the stately and impressive order which everywhere else prevails.

Lastly, there is the Evolutionary Process itself. This is also a source of considerable suffering, and chiefly so for this reason, that inseparably bound up with it there is the fact of physical death. But, as pointed out in the second chapter of this book, death and reproduction and the gradual development of the individual from the germ-cell onwards—not to speak of a number of other things which we have since discussed—are all mutually implicated, together constitute, as it were, a single undivided whole. If Evolution was to be, if some such process was essential for the accomplishment of the supreme moral end, the “far-off Divine event to which the whole Creation moves,” then death had also to be. Moreover, if it should turn out that for some at least there will be a life beyond the grave in which the bonds of love and friendship formed on earth will again be knit up, death will then appear as a merely temporary thing, and its sting will be finally removed.

To sum up, I have tried to show in this chapter the very close relation in which, as it seems to me, God’s supreme purpose in the world stands to the great problem of evil. That purpose, so I take it, was at the end of Organic Evolution to bring into existence beings like ourselves capable of choosing freely between right and wrong—a choice which, to be of value, involved suffering, since it was only by such means that truly noble characters could be formed and moral perfection at last attained. This, then, being so, suffering was woven into the very texture of the world from the first. Our dependence on the environment and our continual struggle with it, and all the suffering

therein entailed, were designed to prepare and discipline us for the infinitely more important struggle which was to be carried on in the realm of the spirit. But this would not have been possible, if we had been placed in the midst of surroundings which offered no resistance to our wills, and in which we were shielded from shot and shell and every sort of calamity. As one has well said,¹ "It is the fight, the quest, the conquest, that makes the man. . . . Life's best chance is to wrestle with life, to fight the wind and the weather and to win through."

At the end of Chapter II I remarked upon the somewhat anomalous fact that, whereas the Universe in all its larger aspects presents the appearance of a perfectly ordered whole, this is very far from being the case in the domain of Life, where so much of disunion and strife abound. But the present chapter will, I hope, have made the reason for this plain. Moral development could scarcely have taken place in a world constituted otherwise. But when at last God's Will shall be "done in earth as it is in heaven," it will be seen that the progress has been from order through disorder to order again—an order, however, of an immeasurably loftier kind because of a more spiritual kind.

Lastly, I am far from imagining that all the difficulties in connection with the Problem of Evil have been cleared up. The light of the full moon, as it streams in through my bedroom window, reveals many objects in sharpest outline, but there are still nooks and corners here and there where the darkness remains unrelieved. So it is also, as it seems to me, in relation to this most perplexing problem. What I am disposed to think, however, is that along some such lines as those which I have indicated, the final solution will be found. Meanwhile, if there be any truth, even of a restricted kind, in what has been said, have we not sufficient warrant for believing at least this: that notwithstanding all the suffering which is in the world—and let us not be unmindful of all the pure and innocent enjoyment which is in it as well—Man, God's highest creature on this earth, is of value to Him, and of very great value indeed?

¹ Sidney Walton.

Doubt no longer that the Highest is the wisest and
the best,
Let not all that saddens Nature blight thy hope or
break thy rest,
Quail not at the fiery mountain, at the shipwreck,
or the rolling
Thunder, or the rending earthquake, or the famine,
or the pest !¹

¹ Tennyson, *Faith*.

CHAPTER XXXV

THE MORAL CHARACTER OF GOD

THE following is a brief epitome of the argument contained in this book up to the present.

First, in all its earlier portions (Chapters I to XXIX) the endeavour was to show how extremely difficult it is to give any rational explanation of the world, except as the work of a Supreme Intelligence—that same Intelligence whom in the language of religion we speak of as God. The proofs in support of this were based almost entirely upon the phenomena of Life—Life looked at successively from the physiological, the embryological and the evolutionary standpoints. What was chiefly insisted upon was the remarkable purposiveness of these phenomena and the complete failure of every attempt hitherto made to account for them along purely mechanistic lines, and to account more especially for those most extraordinary facts of all in connection with the development of the individual from the germ-cell onwards. Hence in the chapter entitled “A Fresh Departure” I pointed out how we seemed compelled to attribute to every organism, whether animal or plant, an inner principle of life which was essentially of the nature of mind and which we agreed to call its “psyche.” Again, inasmuch as, according to the doctrine of Evolution, all living things are, so to speak, blood-related to one another, and constitute, therefore, but a Single System, we were led to ascribe the origin of this System to a Single Mind, which, as I afterwards tried to show, must be thought of as one with the Mind which is present everywhere, and which has brought all things, whether living or non-living, into existence.

But God, besides being Intelligence, must also be con-

ceived of as Will, for the Universe has not remained merely an ideal representation in His Mind, but has been gradually attaining realisation through a process of which the final goal has not yet been reached. Moreover, we must not conceive of God's relation to the world as resembling, except in a very distant sort of way, the relation in which we stand to the works of our own hands. For whereas we can only act upon things externally, God can, and always does, act upon them internally, seeing that His Life at every instant penetrates and informs the Universe as a whole.

But besides Intelligence and Will, could we attribute to God anything corresponding to Feeling and Emotion in ourselves? To this question we thought that an answer was given by the surpassing Beauty of the world, which surely could never have been got into it, unless there had been a joy in beauty, and over the production of it, in God Himself. But this could scarcely be the only kind of emotion attributable to Him; and if so, there was at least the possibility of something in Him akin to what we experience in ourselves as love—a love of which we might perhaps be the recipients. But about this for the present we could not tell; so I tried to answer, first, the far less difficult question, as to whether the world at large, and we men in it more particularly, were of any real value to God.

The positive argument in favour of this was then stated, while at the same time it was frankly admitted that there were certain more or less grave objections which might be urged against it. With these I have endeavoured to deal in the last few chapters, although with what measure of success I must leave it to my readers to decide. The principal point, however, which emerged from the whole discussion was that the great Purpose which God all along had had in view was a moral one, viz. the bringing into existence of beings like ourselves, who should be able to choose between certain higher and lower impulses, and who by choosing aright should gradually bring their wills into conformity with His own. But as this, to be of value, could only be accomplished through self-sacrifice and a

considerable amount of suffering, we were at last given a clue as to why suffering had been allowed to enter, and to occupy so large a place in, our world.

In approaching now the special subject of this chapter, viz. "The Moral Character of God," may we not say at once that it seems almost impossible to conceive of God as a Being morally indifferent, if it was really a moral end, to be finally achieved in Man, up to which He had been working during all the earlier evolutionary ages? Just as all that there is of beauty in the world testifies to His inherent love of beauty, so, we may now add, all that there is of goodness in the world testifies to His inherent love of goodness, although there is, of course, this important difference between the two, that whereas the beauty is entirely of God's making, the goodness is by its very nature dependent upon Man's willing co-operation. At the same time, there would never have been in Man any goodness at all, apart from those higher moral impulses, the origin of which we can only ascribe to God Himself.

It is true that human life, as we find it to-day, presents a strange and somewhat humiliating spectacle. From the moral point of view it appears little better than a confused jumble of all sorts of elements, good, bad and indifferent. At one end of the scale we have those pure and lofty souls, the very salt of the earth, who are continually endeavouring to bring their wills into more perfect harmony with God's, while at the other end we have all the rogues and villains by whom society is perpetually being plagued. Between these two extremes there are those who have exhibited nearly every conceivable admixture of good and evil, so that we should probably be right in saying that the average human individual offers an example of almost complete moral indifference.

If, then, we were to judge of the Character of God by that of the average human individual, our present inquiry would not, I am afraid, yield any very encouraging result. But why should we adopt such a course? Surely God's Character is to be judged, not by those imperfect specimens of humanity who have failed to obey His high summons,

but by those individuals rather who have freely and gladly responded to it. It is to such as have fulfilled the Divine ideal set before them, or at least have laboured hard to do so, that we must look for the revelation of God's inmost character; not to such as have rejected it, or shown themselves utterly indifferent to it.

May I be allowed here the use of an illustration? If we go back some four hundred years, we come to a time when it was the custom in several of the leading cities in Italy for an artist to employ in his studio a number of pupils whose business it was to stretch his canvases, to mix his colours, and frequently to paint pictures themselves under his supervision. It would, of course, be only the most advanced and competent among them who would be permitted to do this last, and especially if the works when finished were to go forth to the world, as we know they sometimes did, as the artist's own productions. Let us now imagine that in one of these studios none of the pictures were ever really painted by the artist himself, but that he did all his work through his pupils, providing them, to begin with, with very full sketches, and afterwards giving them every possible assistance in the way of suggestions, in some cases even guiding their hands as they held the brush. Naturally the pictures so produced would differ among themselves enormously in quality. Not all the pupils would be equally apt, and it might well happen that some would very imperfectly follow the instructions they had received, thinking perhaps that they knew better than the artist himself; whilst others entirely regardless would turn out nothing but ugly daubs with harsh and glaring colours, and in which all sense of harmony and due proportion was lost.

Now if pictures such as these—so medley an assortment—had in course of time become scattered abroad among the various galleries of Europe, what would be the proper way centuries afterwards of trying to get back to the original intention of the artist, and to a just appreciation of those great ideas which he had sought to transfer to canvas? Most certainly it would not be the proper way to treat all

the pictures as of equal worth, or to regard just a chance selection of them, which were neither very good nor very bad, as in any sense truly representing him. Knowing the peculiar circumstances under which the pictures had been produced, the right course would be to single out as typical only the very best, and to say,—“These are the ones which most faithfully reveal the inner mind and purpose of the Master, whoever they may have been who actually laid on the pigments.”

The meaning of the parable is, of course, obvious. God's Character, as I said just now, is not to be judged by that of the average human individual, but by that of the noblest specimens of our race, by those who have yielded themselves most unreservedly to the higher impulsions, have offered the least obstruction to the working in them of the Divine Will. It is to the excellent in the earth that we must go, if we want to know what God is really like—to the world's true heroes, to the pure, the brave, and the gloriously unselfish ones, who regardless of all cost have spent their lives in the service of, and for the good of, their fellows. It is through them, as through a piece of clear transparent glass, that the Heavenly Radiance most conspicuously shines ; not through those whose natures have become foul and muddled by reason of folly and sin.

And here it will be well perhaps to take note, that although a noble life may be said to be made up of noble deeds, this only half expresses the truth. The isolated noble deed may command a certain amount of admiration, but the sentiment is not to be compared with that which is awakened in us by a truly noble character. The latter, to employ another illustration drawn from the world of art, is like a fine piece of statuary by some famous sculptor. However much we may wonder at the dash and brilliancy of the successive strokes with which he belabours the block of marble, we must wait till the beautiful design stands forth complete, before we can rightly applaud his genius or enter into the motives which inspired him in this particular work. Cannot we find something parallel to this in God's dealings with ourselves ? Those secret impulsions emanating from Him

and moving us to the performance of noble deeds have this for their final purpose, viz. the shaping of our characters into ever closer correspondence with His ideal of what He would have us become. But how, if this is so, can God be conceived of otherwise than as a moral Being?

Again, I will put the question,—If God in Himself were possessed of no love, no sympathy, no tender compassion and no readiness, I may add, to make any sacrifice for the sake of others, how came these splendid virtues, these fair gifts and graces, to spring up on our earth, to flourish like so many flowers on the dark soil of humanity—that humanity which had inherited from beneath only the lower impulses, the purely self-seeking propensities and desires? If God's love, His sympathy, His tender compassion, His willingness to forgive and perchance to suffer, are henceforth to be to us no more than empty phrases which have lost all their significance, then we are led to the strange, the anomalous conclusion, that at the end of His great evolutionary process He has brought certain beings into existence, many of whom morally considered are far higher and nobler than Himself. It is an idea which I for one find extremely difficult to entertain.

The loving worm within its clod
Were diviner than a loveless God
Among His worlds, I will dare to say.¹

The psalmist somewhere speaks of "the beauty of holiness." If, however, it should be asked, "Why does it so seldom reveal itself?" the reason of course is, that in the vast majority of human lives, even if we choose the best, there is not that steadfast adherence to the moral ideal which alone renders it possible. It is here as in some piece of art, a few bad strokes of the brush or of the chisel will often entirely spoil the effect. The conception, as it originally lay in the artist's mind, may have been most admirable, but somehow the carelessness of his execution, or perhaps the circumstance that too frequently he went to work in an uninspired mood, has ruined the result in so far as the

¹ Browning, *Christmas Eve*.

onlooker is concerned. It is the same in reference to human lives. In spite of a good deal in their characters which is highly estimable, there is often much alongside of it which is of inferior quality, so that we are not greatly impressed by it; it fails to call forth our veneration and love. It is only in those lives which are *verging* on perfection that the real "beauty of holiness" begins to exercise its charm—to put forth all its wonderful power of attraction. It is only in such lives, too, that we seem to catch far-off glimpses of the essential Divine Nature.

And now IF—I am not venturing here upon any positive assertion, but am simply saying "if"—IF in the course of human history there should have happened to come One whose life not only *verged* on perfection, but actually attained to it, so that in Him the full splendour of the moral ideal shone forth, as it has never done either before or since, would not such a One be indeed God's highest revelation of Himself, His one pure, unspotted Image here upon this earth? And would He not in virtue of this become to men of all succeeding ages the bright Beacon intended by God to point them continually onward to whatever heights there might still remain of moral and spiritual achievement? I have expressly used the word "intended" here because, if this thing really happened, it could not have come about by mere chance, seeing that—as in all the previous chapters of this book I have tried to show—purpose, or intention, rules everywhere throughout the Universe, and especially, so I am constrained to think, in all those big events in which lie the hidden seeds of the world's higher progress in the future.

I must ask the reader, however, to regard the above paragraph as no more than a parenthesis. Whether such a One, as I have supposed, did actually walk this Earth some 1900 years ago and live that Life, with the story of which we are so well familiar, and whether the claims which He is said to have put forward can be substantiated—these are matters which can only be decided on historical evidence; but with historical evidence, which in this particular instance is of very considerable complexity, this

book has nothing whatever to do ; it lies altogether outside its purview.

There is only one other matter to which reference need be made. It may possibly be asked, "If, as argued in the last chapter, all moral action, to be of value, involves a certain amount of suffering, and if it is only through suffering that human character can advance towards perfection,¹ to what extent have such ideas any application to God Himself? In other words, in conceiving of Him as a Moral Being, are we obliged to conceive of Him as a Suffering Being as well?" It appears to me that we are so obliged, and that in support of this the three following considerations may be adduced, although they may not all be of equal weight.

1. If God is really capable of joy—and apart from a certain kind of joy in Him the world could never have been as beautiful as it is²—must He not also be capable of suffering, which is joy's opposite? The possibility of the one seems to carry with it the possibility of the other.

2. If compassion and sympathy, as shown by men towards one another, have their counterparts in the Divine Nature, and, indeed, would never have existed in our human world at all unless they had previously existed in God, do they not strongly point to the same conclusion? For to sympathise with any one who is in suffering means, according to the derivation of the word, to "suffer with" them, to share in their pain or grief, whatever it may be. Again, if human love often has its disappointments, as when it is never or only very imperfectly returned, may not the same hold true of the love of God?

3. Once more, if God's presence and power extend throughout the Universe and are manifested not least in all the various forms of sentient life up to Man, who shall say that the sufferings which we, or any of His other creatures, may have to undergo, He may not also participate in, because of the close and intimate relation in which He stands both to us and to them? When our bodies have sustained some

¹ Compare Epistle to the Hebrews, ii, 10.

² See Chapter XXX, p. 459.

severe injury causing us much pain, how can we be sure that it may not be shared in to some slight extent by the parts which have been specially affected, and even by the individual cells of which they are composed? So, too, it may be with God. Just because His Life informs and permeates all, the pain with which "the whole creation groaneth and travaileth together until now" may well be His pain also, and, if so, a pain far more intense perhaps than any which we as human beings ever have to endure.

CHAPTER XXXVI

THE HEREAFTER

“If a man die shall he live again?” That question put centuries ago into the mouth of Job is as urgent to-day perhaps as ever it was, and particularly so in view of the modern tendency to assume a purely agnostic attitude towards it, and occasionally to deny outright the possibility of any life beyond the grave. It has been argued that since we only know of mind in its association with that exceedingly complex material structure, the brain, the odds are greatly against any prospect of its survival, and especially as at death the said material structure, like every other part of the body, immediately begins to fall to pieces and to be resolved into its constituent elements. Again, that there may be consciousness, not only apparently must there be a brain, but a brain in a state of constant activity, with nervous currents flowing through it—a thing only possible, so long as it is being properly supplied with blood. Moreover, anything which like an anæsthetic, or a blow upon the head, tends to interfere with these currents, tends also, temporarily at least, to destroy consciousness. Hence, on these and other grounds it has been contended that mind, instead of being like matter a distinct entity, is merely a function of the brain. The stomach digests, the lungs breathe and the heart beats, and in a somewhat similar fashion the brain thinks. It is as unreasonable, therefore, to suppose that thinking goes on after death, as to suppose the like to be true of digestion, respiration or the circulation of the blood.

Now, in the endeavour to meet this somewhat plausible theory, I shall refrain, to begin with, from basing any argument upon the conclusions reached in the last few chapters, fully as I intend to make use of them afterwards.

Meanwhile, let us remember that unless the soul can be shown to be an entity in some sense quite distinct from the body, and presumably capable, therefore, of an independent existence, we may as well abandon at once all hope of its survival.¹

1. Let us begin by imagining a world in which no process answering to organic evolution has ever occurred, but which is nevertheless inhabited by a number of incorporeal beings possessed of an intelligence akin to our own. We will further imagine that a human body in a state of complete preservation, but in which all life has become extinct, has by some strange accident been discovered on this world and is being subjected there to very careful and minute examination. Now what would the inhabitants be likely to make out as to the purposes to which its various organs and systems of organs had been put? They would not be long, I think, in arriving at the secret of the circulatory system. The peculiar structure of the heart, with its various chambers communicating either directly with one another or indirectly through the arteries, capillaries and veins, would, combined with the remarkable character and position of its valves, almost inevitably suggest to them the idea that the entire arrangement of the system had been for the purpose of causing some unknown fluid to circulate through it. And this conclusion would be put beyond all doubt if some of the said fluid, viz. the blood, were found still lingering in any of the above-mentioned vessels.²

Similarly, it would not take long for them to arrive at the secret of the muscular system. It would be observed that in the greater number of instances the two extremities of a muscle were attached to bones between which a joint intervened, so that if from any cause a muscle were made to contract, the bones would be moved in a certain definite manner with respect to each other. It would be observed, too, that there was generally another, an opposed muscle, for the purpose of bringing the bones back to their previous

¹ "The discrimination between an entity and a function is vital."—Prof. A. N. Whitehouse, *Science and the Modern World*, p. 178.

² For a fuller account of the Circulatory System see Chapter VIII.

ANALYZED

position. Confirmatory evidence would be supplied by the extraordinary strength and tenacity of the tendons with which many of the muscles terminated; and, further, it would be found that, just where according to supposition the two bones had worked on one another, they were capped with pieces of cartilage, very smooth and highly lubricated, for the obvious purpose of diminishing friction. Lastly, it would be impossible to mistake the meaning of the ball-and-socket joints at the hips and the shoulders.¹

If, however, these supposed inhabitants were to turn their attention to the nervous system, they would not find the problem presented to them quite so easy. They would discover, no doubt, that it was composed of a vast multitude of organic elements, viz. the neurones, answering to the cells in all the other parts of the body, but with this difference, that proceeding from them there were certain remarkable prolongations of their substance, the so-called nerve fibres, some of which were of very considerable length. They would also discover that in the spinal cord, and more particularly in the brain, these cells and fibres were connected up with one another in the most intricate manner, so that the entire arrangement might be compared to an immense telephone exchange with innumerable wires radiating from it in every direction. This might lead them perhaps to suspect that during life these fibres had acted as channels for the transmission of certain currents not altogether unlike electricity, and especially as the axis-cylinder in each was found to be cased in two sheaths, which might very well have been for the purpose of effecting insulation. Again, as the fibres could be traced into practically every part of the body, the inference might possibly be drawn that the object of the entire system had been to link up all the various organs together, so as to secure their harmonious working.² Now whether or not our supposed inhabitants would be able in their speculations to get quite so far as that, of this we may be absolutely sure that, not possessing any bodies of their own, they would utterly fail to penetrate

¹ For a fuller account of the Muscular System see Chapter IX.

² For a fuller account of the Nervous System see Chapter XI.

into the innermost secret of the nervous system, as it exists at all events in ourselves. It would never, for instance, for one moment occur to them that concomitant with the nervous currents—but with such only as had flowed through certain restricted areas in the brain—there had been anything corresponding to sensations, memories, emotions, judgments and acts of volition. And the reason, of course, is plain. Between mental states like those just mentioned and changes of a physical nature taking place in nervous tissue there yawns an unbridgeable chasm. There is nothing in the one set to suggest the other even remotely, and hence to compare their mutual relations to the relations existing between such organs as the stomach, the heart and the lungs, and their respective functions, is to follow an entirely false trail.

2. Again, highly complicated as is the *arrangement* of the various elements—cells and fibres—entering into the composition of the brain, they are, with the exception of certain comparatively small differences, practically all alike, and therefore do not seem in any way to correspond with that immense diversity which characterises our mental states, whether they happen to be preponderantly of the intellectual, the emotional or the volitional type. To consider only our sensations, can we imagine a greater contrast than that which exists between sight and hearing? They seem to have nothing whatever in common, and yet the areas in the brain which are respectively assigned to them exhibit only the slightest amount of structural difference.

3. In Chapter XX I pointed out how every attempt hitherto made to explain mechanistically the facts of embryonic development had most signally failed; and this led me in the chapter immediately following to postulate in the case of every animal and plant the existence of an inner Principle of Life which I ventured to call its “psyche.” “This inner Principle,” I said, “although imperceptible by our bodily senses, must be conceived of as pervading the entire organism and as controlling all its various activities.” It must be conceived of also as “the secret cause of its development from the germ-cell onwards, and as being

in its essential nature akin to mind, although doubtless differing from the fully conscious mind in several important particulars." But if that be really so, it is difficult to conceive how a controlling Principle of the kind just mentioned can be merely a function of that which it controls.

4. Further, when dealing with Memory in Chapters XXII and XXIII I endeavoured to show that the impressions made upon us by our past experiences cannot possibly be stored away, as has frequently been assumed, in the substance of the brain, but rather in the mind itself. But this more presupposes that the mind is a distinct entity, however closely it may be associated for the time being with a bodily organ. Memory, it must not be forgotten, enters as an essential element into all our other mental processes. It is implicit in all our perceptions, judgments, trains of thought and of reasoning. Moreover, it is only by means of inductions based upon recollections of our past experiences, that we are enabled in any degree to forecast the future and to direct our energies towards the realisation of our various purposes.

5. We seem to reach the same conclusion if, as I also tried to point out, the real reason why an embryo repeats in its development its successive ancestral stages, is that even in its earliest stage of all, when it is no more than a solitary cell, it is already charged, so to speak, with all the memories corresponding to the stages which are to follow. It is not, however, the cell considered simply as a material object which is so charged, but rather the psyche, its hidden underlying Principle; seeing that, as mentioned in the last paragraph, it is only in that which like the psyche is of a mental nature that memories of any kind can be lodged.

6. I may also remark that the habit, which has so largely prevailed, of regarding the mind as simply a function of the body has no doubt been due in part to a certain inborn propensity, urging us to reduce all known phenomena to as few fundamental principles as possible. Matter and Energy, just these two—so it has sometimes been alleged—are the only real entities in the Universe, and by them

everything else is to be explained. But even in the case of Energy is that quite so self-evident? We saw in Chapter III that the doctrine of the Conservation of Energy could only be considered true, when we included under the term "energy" all its potential manifestations. But surely it is only in a sort of metaphorical sense that we can speak of the energy of a suspended weight, of a coiled-up spring or of a complicated carbon compound. To say the least, this extension of the meaning of the term "energy" to these several potentialities seems to render the conception somewhat elusive. And, besides, we have Professor Whitehead telling us that "the physicist's energy is obviously an abstraction."¹

Apart, however, from what has just been said, we have been assured on the highest authority that, in addition to Matter and Energy, there is at least one other entity, viz. the Ether, the importance of which in the general scheme of things it would be impossible to exaggerate. By its inconceivably rapid undulations it is the bearer to our little world of whatever light and heat it receives; also it fills all interplanetary and interstellar space out to the furthest limits of the Universe. Not only so, but it penetrates into all the interstices of things, inserting itself between the molecules and atoms, and between even the protons and electrons, so that they never come into any real contact with one another. That this should hold true of gases like oxygen and hydrogen and the air we breathe is not surprising; but it is very surprising, when we are told that the same holds true of so solid and dense a mass as a block of steel. Of this everywhere-prevailing Ether, Clerk Maxwell once wrote: "No human power can remove it from the smallest portion of space, or produce the slightest flaw in its infinite continuity." Moreover, according to Sir Oliver Lodge, gravity, cohesion, chemical affinity and a number of other most remarkable properties, find their explanation in it; and although he describes it as "perfectly limpid," and as offering no resistance to the passage of other bodies through it, it is nevertheless "enormously denser than any form of matter

¹ *Science and the Modern World*, p. 47.

—just about a million million times more than water.”¹ Again, he says, still referring to the Ether: “In every cubic millimetre of space”—*i.e.* in a cube measuring about $\frac{1}{25}$ th of an inch each way—“we have a mass equivalent to what, if it were matter, we should call a thousand tons, circulating internally, every part of it, with a velocity comparable to the velocity of light, and therefore containing stored away in that small region of space an amount of energy . . . expressible as equal to the energy of a million horse-power station working continually for forty million years.”²

I have dwelt on this subject because if, to account for the familiar phenomena of gravity, cohesion and chemical affinity, as well as of light and heat, we are asked to believe in the existence of this invisible and impalpable entity called the Ether—possessed, too, of such extraordinary, almost incredible properties—why should we be forbidden to believe in the existence of another invisible and impalpable entity, *viz.* Mind, to account for those unique and otherwise wholly inexplicable phenomena connected with Life? The persistent effort in certain quarters to explain Life and all that is of a mental nature in terms of Matter and Energy alone—and to do so in spite of so many indications to the contrary—seems to me to savour strongly of that dogmatic spirit which in earlier times proved such a serious obstacle to the progress of knowledge.

There is another point. It is not only true of Mind, but of both Ether and Energy as well, that our acquaintance with them has only been gained through their association with, and observed effects upon, Matter. Apart from Matter we should never have become aware of the existence of any of them. It may be the case, of course, as Sir Oliver Lodge suggests, that Matter will ultimately turn out to be a special modification of the Ether. It may likewise be the case, that both Matter and Ether will resolve themselves into special forms of Energy, and that all three of them will come at last to be recognised as so many manifestations of

¹ See *Ether and Reality*, pp. 88, 89. The density of platinum, which is the densest substance known, is only about twenty-one times that of water.

² Sir Oliver Lodge, *The Ether of Space*, p. 95.

some one underlying reality—possibly Mind. But these are subjects rather of philosophical speculation than of established scientific fact. Hence for the present we may be legitimately allowed perhaps to accord to each of the four just mentioned a somewhat similar status in the Universe, and to regard them all—Matter, Ether, Energy and Mind—as so many separate entities. The main point, however, in reference to the last three of them is, that we only know of them in their association with the first, viz. Matter, so that Mind does not stand in this respect alone.

And here I should like to call attention to a peculiar property, which Energy and Mind appear to possess in common. Energy, we know, is continually being transferred from one material body to another, as when, for instance, a billiard ball on striking another communicates to it a portion of its motion, or when the heat of the burning coals in a furnace is communicated to the water in an adjacent boiler. Similarly, in every organism the living Principle, which at bottom is identical with Mind, is continually being transferred, although less evidently and much more slowly, from one collocation of atoms and molecules to another. There is on the one hand a constant inrush of particles in the shape of food and fresh oxygen, and on the other a constant outrush of particles in the shape of water, carbon dioxide and urea. The consequence is, that in course of time the entire substance of the body becomes changed, whereas the psyche or soul maintains throughout its self-identity.¹ But this is tantamount to saying that Mind, like Energy, is an entity capable of an indefinite succession of material embodiments.

I may point out also that between the two there is possibly another analogy. Energy not only embodies itself in gross matter, and very largely as heat, but is continually passing over into the Ether, in which it assumes an entirely new form, viz. that of radiation. Thus the heat of the sun, which takes rather more than eight minutes to reach the

¹ I have somewhere seen it stated, although I will not vouch for its truth, that the substance of the brain undergoes a complete change in the course of only a few weeks.

earth, is, strictly speaking, during its journey not heat at all, but Energy in its radiant, its ethereal manifestation. On its arrival here, however, it is reconverted into heat, as the result of its contact with the gross matter of which our little world and its surrounding atmosphere are composed. May it not, therefore, happen perhaps at the moment of death, that the soul passes over into, and embodies itself in, something which is not gross matter at all? I throw it out as a suggestion.

7. There remains yet another consideration, perhaps the most weighty of all. We have already seen ¹ how the facts in connection with the development of the individual constrain us to believe that in every organism there is an unseen Principle constantly at work, which is of the nature of mind; and we have likewise seen ² how the facts, in connection with the development on our planet of Life as a whole, constrain us to believe in the existence of a Single Mind, immeasurably superior to any human mind, and which during the past well-nigh interminable ages has been the secret cause of Organic Evolution. Moreover, in Chapter XXIX we were gradually led up to the conclusion that this same Mind must also be thought of as the Supreme Mind from whom the entire Universe proceeds.

Now if we once admit the truth of this, then Mind can no longer be regarded as a merely ephemeral thing, just a passing incident in the history of the Universe. Neither can it have derived its existence from Matter and its forces, or indeed from anything outside itself.³ Hence quite clearly it is Mind, not Matter, which really sits atop in the Universe. But if this be so, and if the Mind of God is in no sense dependent for its existence on its association with anything which is of a material nature,

Not tied or manacled with joint or limb,
Nor founded on the brittle strength of bones
Like cumbrous flesh,⁴

it is at least conceivable that a lesser, a finite mind, may under certain circumstances continue to live on, although no longer

¹ Chapter XXI.

² Chapter XXVI.

³ Chapter XXIX.

⁴ Milton, *Paradise Lost*, Bk. i.

conjoined with such a structure as, for example, a human body. To deny the possibility of this would be sheer dogmatism, when once the existence of God has been conceded.

Up to this point I have simply been trying to dispose of the idea that the mind or soul is only a function of the body, and that, therefore, like all other functions it must necessarily cease at death. That it should necessarily *survive*, however, is quite another question, and one about which we may not be able in every case to feel quite so certain—that is, simply on the strength of the evidence considered in this book. Obviously there are several possibilities. We may suppose that at death the soul does actually cease to be, in spite of its being an entity distinct from the body; or we may suppose that along with the body it gradually disintegrates. Or, again, we may suppose that it completely detaches itself from the body and continues its existence for a shorter or longer period; or, once more, that this period is indefinitely extended—in other words, that the soul is by its very nature immortal, or at least possesses the power to become so. Finally, we must not overlook the possibility, that there may be differences in this respect among different individuals, and that what happens to some may not perhaps happen to all.

Now I do not intend to enter into any detailed discussion of these various alternatives. It will be enough if, making use of certain of the conclusions arrived at in the more recent chapters of this book, I endeavour to show what grounds there are for believing that in the case of many, if not of all, there will open up a life beyond the grave which, again in the case of many, may very well prove to be unending. Parenthetically I may remark that the phrase “an immortal soul” nowhere occurs in either the Old or the New Testament Scriptures, and that in the latter more especially “eternal life” is represented not so much as man’s natural heritage, but as something which he is continually to strive after and to render himself worthy of.¹

¹ See Matt. vii, 13, 14; xix, 16, 17, 29; John iii, 16; Acts xiii, 46; Rom. vi, 22, 23; 1 Tim. vi, 12, 16; 1 John iii, 15; v, 11, etc.

Now in the chapters just referred to I gave good reasons, as I thought, for believing that the world must necessarily be of value to God, in view of those immense æons of time during which He had been at work in it, gradually shaping it in accordance with His eternal plan. Not only so, but it must have become increasingly of value to Him, as one by one the different stages in the Creative Process were reached—when, for example, Cosmic Evolution was succeeded by Organic Evolution, and Organic Evolution by that still higher form of Evolution which is now being wrought out in Man. Again, mere size, so we saw, gives no indication of the real worth of anything. Of a living organism, with all its wonderful arrangement of parts conspiring together for the realisation of certain definite ends, it may truly be said that God is far more fully revealed in it than in those vast masses of heaped-up material of which the mountains, the seas, the atmosphere and the heavenly bodies are composed. There is a sense in which the humblest flower excels in this respect even the mightiest star. So when at last Man emerged upon the scene, the final product and crown of all God's previous toil, and endowed by Him with all those marvellous powers which raise him so far above the brute, how could he be other than of quite special value in His sight? Two things, of course, should be remembered here: first, the extreme improbability, as I have already pointed out, of organic evolution giving rise to any creature on the earth who shall be higher than Man;¹ and secondly, the assumption, which I think we are quite justified in making, that in whatever other world organic evolution may happen to run its course, it will probably terminate in the production of beings in all essential respects resembling ourselves. For throughout the Universe all rational minds, wherever found, must necessarily be akin—one might almost say must necessarily be human—however much they may differ from us and from one another in outward appearance, internal organisation and degree of mental development.

But to resume. If, in spite of what has been said, death

¹ See Chapter XXXI.

is nevertheless to make a complete end of all, and for none of us is there to be any chance of escape from so harsh a doom, consider for a moment what that would mean. It would mean that all the labour which in the countless bygone ages God has bestowed upon His world is eventually to prove abortive, nothing of any permanent value is to be accomplished by it, no great goal is ultimately to be attained. The Universe, which during all its later evolutionary stages has shown such manifold and unmistakable indications of purpose, is to turn out at last to have been utterly devoid of purpose as a whole. God intended nothing by it, and He is going in the far end to hand it over to destruction—to the destruction, at least, of all that has been highest and noblest in it and most nearly allied to Himself. And so Man and all life upon the Earth having been extinguished,

The homeless planet at length will be wheeled thro' the
silence of space,
Motherless evermore of an ever-vanishing race.¹

If, however, there be a God who in any real sense cares for His world, and above all cares for us, what are we to say of the utter futility of such a proceeding? It would be as though the husbandman, who had diligently ploughed his fields and sown them, and had waited patiently during the summer months for the coming of the harvest, should at the proper season send out his men to reap and gather in the sheaves, but only that he may cast them upon the dunghill or commit them to the flames.

But the argument which I have just employed receives still further confirmation, if we are prepared to admit the conclusions reached in Chapter XXXIV. Man rises above the brute not only in virtue of his superior mental powers, but because he is a moral being with the choice set before him of following either his higher or his lower impulses. Although, however, they have both been implanted in him by God, it is nevertheless, so we saw, the Will of God that he should follow the higher in preference to the lower ones, whenever they may happen to clash. To do this, however,

¹ Tennyson, *Despair*.

often involves considerable loss and pain, amounting in many cases to very serious sacrifice ; but then it is only through the voluntary acceptance of such loss and pain that actions can become in any real sense meritorious. Again, it is only by means of a prolonged course of such actions, extending perhaps through many years, that moral character of the highest type can be slowly built up. So true is it, that only through suffering can any of us advance towards perfection.

And it is God Himself who has ordained this. That His high intention in us might be fulfilled, He has deliberately subjected us to this stern discipline ; but for what ultimate end ? For none that I can see, if He is to trample us under His feet at last, and we are all to go down for ever into the darkness and silence of the tomb.

What the philosophies, all the sciences, poesy, varying
 voices of prayer ?
 All that is noblest, all that is basest, all that is filthy
 with all that is fair ?
 What is it all, if we all of us end but in being our
 own corpse-coffins at last,
 Swallowed in Vastness, lost in Silence, drowned in the
 deeps of a meaningless Past ?¹

If that, however, is to be the final goal, not only will the Evolutionary Process to all intents and purposes have run its course in vain, but in vain will have been all men's efforts to bring their wills into harmony with God's through obedience to those higher impulsions which He Himself has put within them. Yet why should He have lured them on in this pitiless fashion to believe in Him as One who would be faithful to their trust and would never, therefore, forsake them, if—taking the words in their quite literal sense—to “perish everlastingly” is to be their only reward ? Or how did it come about that He, the pitiless One, should ever have planted pity in men's hearts and, to move them on to high and noble deeds, have kindled in them such sentiments as generosity, kindness, forbearance, love ? These things must surely have had their original seat in

¹ Tennyson, *Vastness*.

Him, have formed part of His very Being. Will He then esteem them as of no value at all, utterly unworthy of being preserved, when towards the end of His great Creative work they are seen blossoming forth afresh in all their pristine beauty in human lives?

If gazing up at the splendours of the midnight sky, we should find ourselves asking with Tennyson,—

“ Will my tiny spark of being wholly vanish in your
 deeps and heights?
 Must my day be dark by reason, O ye heavens, of your
 boundless nights,
 Rush of Suns and roll of systems, and your fiery clash
 of meteorites? ”

perhaps to us also, as to him, may come back the answer,—

“ Spirit, nearing yon dark portal, at the limit of thy
 human state,
 Fear not thou the hidden purpose of that Power which
 alone is great,
 Nor the myriad world, His shadow, nor the silent
 Opener of the Gate! ”¹

So at last we come, my readers and I, to the end of our long journey. Much ground has been covered and there have been many windings in the road, but we have sought throughout to keep the main goal steadily in view. We have tried to get down beneath the mere surface of things—the Universe, that is, as it presents itself to our bodily senses—and to find out what we could about that Unseen Reality, of which the Seen is but the outward, the ever-changing Manifestation. Whether, as the result, we have gained any firmer hold on those great basic truths on which all Religion rests, is a matter that I must leave to my readers to decide. If such, as I trust, has been the case, then perhaps a certain broad platform has been reached on which others, more skilled than myself, may be able to build in the future.

¹ Tennyson, *God and the Universe*.

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